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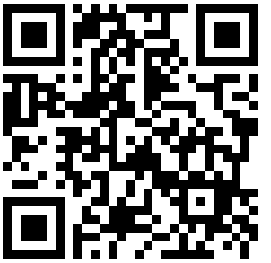

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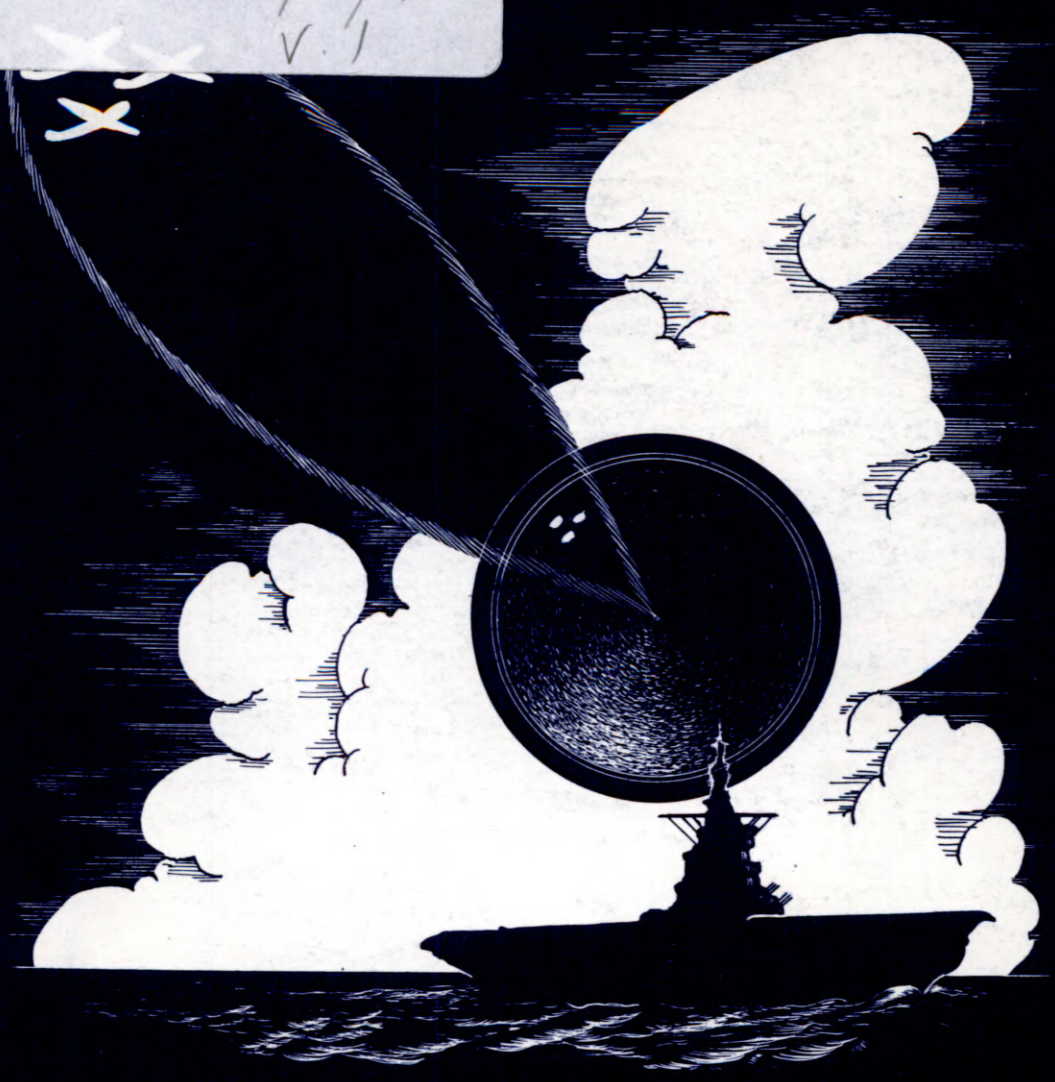

RADARMAN 3 & 2, VOL. 1

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10146-F

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PREFACE

This book, based on the *Manual of Qualifications for Advancement in Rating*, NavPers 18068, is written as an aid in preparing for advancement to Radarman 3 or 2. It is one of a series of NAVY TRAINING COURSES designed to give enlisted men the information necessary to perform their duties.

Inasmuch as so many of the Radarman's duties are classified, it is impractical to set forth all of his duties in an unclassified training course. The *Radarman* 3 & 2 training course is, therefore, published in two volumes. This one (Volume 1) is unclassified, while Volume 2 is assigned a Confidential Modified Handling Authorized classification.

Treatment of certain qualifications relating to electricity, electronics, and technical maintenance is excluded from this book because this information is adequately treated in *Basic Electricity*, NavPers 10086, in *Basic Electronics*, NavPers 10087, and in *Basic Hand Tool Skills*, NavPers 10085. Knowledge gained from basic mathematics texts will also help you to become a better operator and aid you in maintaining the gear.

This book was prepared by the U.S. Navy Training Publications Center for the Bureau of Naval Personnel, and was reviewed by the Office of the Chief of Naval Operation (Op-353) and by personnel of the U.S. Naval School, Radarman, Norfolk, Va.

Printed 1961
Reprinted with minor changes 1962

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CONTENTS

Chapter		Page
1.	The Radarman	1
2.	Radar nomenclature	6
3.	Radar operation and methods	15
4.	Uses of radar	32
5.	Functional components	48
6.	Surveillance radars	69
7.	Plan position indicators	98
8.	Operational techniques	118
9.	Factors affecting radar	136
10.	Pipology	150
11.	Maintenance and safety	164
12.	Telephone and talking procedures	183
13.	Logs, records, reports, and publications	205
14.	Surface plotting	225
15.	Air plotting	242
16.	Maneuvering board	260
17.	Dead reckoning equipment	280
18.	Navigation	298
Appendix		
I.	Answers to quizzes	323
II.	Qualifications for advancement in rating	332
Index		339

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	† E7 to E8	‡ E8 to E9
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E-2.	6 mos. as E-3.	12 mos. as E-4.	24 mos. as E-5.	36 mos. as E-6.	48 mos. as E-7. 8 of 11 years total service must be enlisted. Must be permanent appointment.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training.		Class A for PR3, DT3, PT3. ‡ AME 3			Class B for AGCA, MUCA, MNCA.		
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.				Service-wide, selection board, and physical.	
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		U.S. Naval Examining Center			Bureau of Naval Personnel		
	TARS are advanced to fill vacancies and must be approved by CNARESTRA.							

* All advancements require commanding officer's recommendation.
† 2 years obligated service required.
‡ 3 years obligated service required.
‡ Effective 1 Jan. 1963.

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INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
	FOR THESE DRILLS PER YEAR								
TOTAL TIME IN GRADE	48	6 mos.	6 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	24	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.		
DRILLS ATTENDED IN GRADE †	48	18	18	45	54	72	108	144	72
	24	16	16	27	32	42	64	85	32
TOTAL TRAINING DUTY IN GRADE †	48	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	24	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days		
PERFORMANCE TESTS				Specified ratings must complete applicable performance tests before taking examination.					
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 760, must be completed for all advancements.							
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.							
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.						Standard EXAM, Selection Board, and Physical.	
AUTHORIZATION		District commandant or CNARESTRA					Bureau of Naval Personnel		

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for drills and training duty.

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READING LIST

NAVY TRAINING COURSES

Radarman 3 & 2, Vol. 2, NavPers 10145-A
Mathematics, Vol. 1, NavPers 10069-B
Mathematics, Vol. 2, NavPers 10070-A
Basic Electricity, NavPers 10086, chapters 1, 3-5, 7, 8, and 11
Basic Electronics, NavPers 10087, chapters 1-5, 7, 8, 10, 11, 13, 14, and appendix II

OTHER NAVY PUBLICATIONS

BuShips Technical Manual, NavShips 250-000, chapter 50, part 6; chapter 67, part 12, articles 281 through 314
U.S. Navy Safety Precautions, OpNav 34P1, chapter 18
Handbook of Test Methods and Practices, NavShips 91828-A, articles 3-7 through 3-11
ACP 125, 165 (effective editions)
ATP 1(A), Vol. I, chapters 1, 3-6, 8 and 9
ATP 1(A), Vol. II
NWP 31(A), 32, 33

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.* The following courses are recommended:

Number	Title
B150	Review Arithmetic
B151	General Mathematics I
B152	General Mathematics II
C164	Beginning Algebra I
C165	Beginning Algebra II
B781	Fundamentals of Electricity
B885	Fundamentals of Radio

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified on the active duty orders."

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CHAPTER 1

THE RADARMAN

KEY MAN IN A VITAL JOB

A Radarman is an important man in the combat readiness of his ship. An enemy can be engaged only after he is detected, and your ship's ability to detect an airborne or surface enemy depends upon the alertness and skill of her Radarmen.

A Radarman starts as an operator of radar equipment and as a plotter and status board keeper. As your knowledge of your specialty increases, your duties will take you into the broader fields of aircraft control, gunnery and missile coordination, antisubmarine warfare, torpedo control, small craft control, and gunfire support.

At the top of your rating, you will become a Chief qualified to control aircraft and serve as an assistant to the CIC watch officer.

This, briefly, is the rating for which you are striking, or in which you are advancing. In this chapter you will learn that a great many plans have been made for your career as a Radarman. You will find that you aren't the only one interested in your advancement; the Navy wants you to get ahead too.

THE RADARMAN RATING

In these days of high-speed aircraft and missiles, the most important single factor in the Nation's defense is early detection of any threat to our country. You are in this rating that specializes in early detection. It takes a keen eye to detect and track a pip. It takes clear thinking to identify the pip. Your rating was born of necessity during the early days of World War II, when CIC was a darkened area in a remote space.

Now, your rating has grown in stature and importance. How often, while your ship was engaged in tactical maneuvers or groping her way through a fog, have you heard the bridge call for recommendations from CIC? Yours is a responsible rating. Be proud of this responsibility and the rating.

RATING STRUCTURE

There are many jobs in the Navy and it takes a great deal of planning to get them all done. Jobs requiring about the same skills, knowledge, and training are grouped under one heading, called a rating. Thus, most of the tasks in detecting and tracking surface and air contacts have been grouped in the rating in which you are interested—Radarman.

Within every rating there are steps for advancement and with each step there is an increase in pay. These steps, or pay grades, are the rates within the rating. The rating is Radarman, abbreviated RD, and the rates are Radarman Third, Radarman Second, and so forth, abbreviated RD3, RD2, etc.

Navy ratings are gathered in a total of 12 groups, with ratings in a particular group occupationally related. This is to say that all the work of detecting and tracking surface and air contacts isn't left to Radarmen. You will find that Signalmen can be mighty handy in detecting and identifying contacts. Radarmen are assigned with Boatswain's Mates, Quartermasters, Signalmen, and Sonarmen in group I, commonly called the deck group.

YOUR CAREER AS A RADARMAN

As a Radarman striker or Radarman Third, you man consoles and repeaters, act as a plotter and a status board keeper, serve as radiotelephone net operator/plotter and sound-powered talker, and maintain the various CIC logs.

While manning radar equipment, you are required to determine the range, bearing, altitude, composition, and identification of detected contacts.

Radar forms a protective screen for your ship and the task organization in which she is operating. Most Navy ships have at least two search radars, one designed primarily for surface contacts, and the other for air contacts. Thus, you can spend the seagoing portion of your career

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aboard any Navy ship. You may be one of the few Radarmen aboard a small ship or one of the many aboard a carrier. Wherever you serve, you will be detecting, tracking and plotting air and surface contacts.

Eventually you will qualify to train other Radarmen for the Navy. You will plan, organize, and direct shipboard radar training programs. If you are sharp enough, you may serve as an instructor or staff member at one of the Radarmen schools or at one of the fleet training centers. As you advance, your contributions to Navy radar will increase. You, as a Chief Radarman, may assist in the preparation of a revision of this book.

Yours is an ever-changing and challenging rating. The Navy is constantly developing new improvements in communications, radar, and means of data exchange. All of these will be worthless without skilled personnel to use them properly. This is your responsibility. The effective functioning of CIC depends upon you.

The CIC layout on new construction embodies the FUNCTIONAL MODULAR INTEGRATED CIC. Personnel and equipment are grouped according to functions by using transparent nonstructural partitioning. This separation minimizes noise and confusion, yet allows visual and oral communications between functional groups. These functional groups are—

Display-decision area;
Surface operations area;
Detection and tracking area;
ECM area;
Weapons control area;
Anti-air warfare (formerly air defense);
Air operations area (this is found on carriers only);
CCA area (carriers only).

With the advent of new data-processing systems, the modulated CIC will have none, or only a few, sound-powered phone circuits.

QUALS MANUAL

The purpose of this training course is to aid you in your efforts to advance in rating. This book is based on the Radarman's requirements for advancement as set forth in the *Manual of Qualifications for Advancement in Rating*. This book, known throughout the Navy as the *Quals Manual*, is one of the most important publications in any enlisted man's career. Military and professional requirements for advancing as a Radarman are contained in this publication. It was used as a guide for the contents of this training course, and it will be used as a guide by the examiners who prepare your servicewide competitive examination. Changes to the *Quals Manual* are issued periodically and new CIC developments are constantly evolving. Thus, while this training course was up to date at the time it was written, changes to the *Quals Manual* and new developments in CIC may in time make portions of it obsolete.

Every ship and station has copies of the *Quals Manual*, but for your convenience the section that applies to Radarmen has been printed as appendix II to this training course.

ADVANCEMENT

Before you can advance in rating, there are certain military and professional requirements you must fulfill.

MILITARY REQUIREMENTS

The military requirements for advancement are those general qualifications which apply to all enlisted personnel, such as watch standing, first aid, and military conduct. These requirements are published in the *Quals Manual*, near the front, preceding the professional qualifications for the various ratings. In order to advance, you must demonstrate your proficiency in each of the military qualifications specified for the next higher pay grade. You also may be required to show your knowledge in the military quals for all lower pay grades.

PROFESSIONAL REQUIREMENTS

Professional requirements for Radarmen are listed in appendix II. These qualifications are those which a Navy enlisted man must have to qualify for a rate (Third, Second, First, or Chief) within a particular rating (Radarman). The higher the rate, the more the man is required to know. A Chief Radarman is required to have a thorough knowledge of all aspects of radar and the functions of CIC.

Appendix II lists the professional qualifications for Radarman at every rate level. You will be interested in those for Third Class or Second Class, depending upon the rate for which you are studying. Notice in the appendix that the professional qualifications are further divided into

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PRACTICAL FACTORS and KNOWLEDGE FACTORS. The practical factors must be demonstrated by DOING. As a Seaman you were required to demonstrate your knowledge of knots by tying them. It makes more sense to tie a knot than to write about one on paper. In the same manner, your ability to distinguish radar contacts is something you will demonstrate at a radar scope.

There must be an entry in your service record to prove you have qualified in the practical factors before you can take the servicewide examination. There is a special checkoff sheet which lists the practical factors for the rate to which you are advancing. This checkoff sheet, Record of Practical Factors, NavPers 760, is kept by your division officer. As you qualify in a practical factor, he enters the date and initials the entry. If you are transferred before you qualify in all factors, the checkoff sheet accompanies your record to the next duty station. You should have a copy of the form for your own record. As major changes to the *Quals Manual* are made, new forms are issued. Minor changes in the quals can be recorded in spaces provided for this purpose on the NavPers 760.

The qualifications listed under knowledge factors in appendix II are those in which you can best demonstrate your knowledge by written examination. These are the professional qualifications upon which servicewide examinations are based. An example of an examination subject is a qual that requires you to know the symbols and procedures used in maintaining geographic, summary, and surface plots.

As mentioned previously, the quals printed in appendix II were taken from the *Quals Manual*. Make it a practice to check the manual to see that the quals have not been changed since they were published here. Your ship's office has a copy of the *Quals Manuals*.

HOW YOU ADVANCE

Before you are eligible to take the servicewide examination, you have to fulfill certain requirements. These requirements are listed on page iv of this book.

When you have met ALL of these standards, you are eligible to take the examination.

NAVPERS 10052

After every servicewide examination you have heard someone ask: "Where did they get THOSE questions?" Most examination questions for RD 3 and 2 will be based on material in this training course. But it isn't practical in a course of this type to include all the information a topnotch Radarman needs. Go into CIC and look at the equipment instruction books, or count the number of tactical publications required to be on hand, and you will know why one text cannot cover all of the radar information. But this isn't as bad as it sounds. The Navy has set definite limits on the material for which you are accountable on examinations. Your fleet examination is based on the reading list for Radarmen contained in NavPers 10052, *Training Publications for Advancement in Rating*. For you, the student, this book provides the titles of the publications and sections of publications WHICH YOU SHOULD STUDY WHEN PREPARING FOR EXAMINATION. Naturally, Radarman 3 & 2, Volumes 1 and 2, are listed there.

Get acquainted with NavPers 10052. After you have read the instructions at the front, there are only two pages of further interest to you. One page contains the sources you should study to meet the military requirements for advancement; the other lists sources for study to qualify professionally as a Radarman. An asterisk marks the training courses which you MUST complete before you can be eligible for servicewide examination.

To repeat, the *Quals Manual* tells what is expected of you militarily and professionally, and NavPers 10052 tells you where to go to find the information. NavPers 10052 is revised annually, usually in March, so make sure you have a current edition when you start your preparations for the big exam. This book is readily available on your ship or station.

ABOUT THIS BOOK

Probably the most sensible approach to your studies is first to understand the general makeup of your text. This book is a self-study course written to help you become a Radarman with the least possible outside assistance. There are features to this book, such as the preface, reading list, and appendices, intended to make your studies easier and more effective.

There is always the temptation to skip the front matter and get on with this thing called radar. But this is apt to be a costly shortcut. If you have skimmed through the front matter to get to chapter 1, there is no better time than now to read that material. The preface, for example,

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will give you the scope of this training course and explain why it was written in two volumes. By all means, read it. You have already discovered how important are the requirements for advancement. Check these carefully. The reading list is the basis of your source information.

Each chapter of this book closes with a QUIZ that should be a quick, reliable check of what you have learned from material you have just covered. The ANSWERS are in appendix I.

Many students lose valuable time because they make little use of the index. You can consider the index as an alphabetical list of the high points or key words in this book. Almost every aspect of radar you can think of will be listed under a key word in the index along with the page or pages where the subject is discussed.

Sometimes the information you need is found more readily in the table of contents. This will be true when the subject is broad or general, as, for example, information about remote plan postion indicators (PPI's). If you need specific information about a particular PPI, then the place to go is the index. Chances are the information will be listed in more than one place under different key words. No matter which of the key words you select, the index will lead you to the correct page.

HOW TO STUDY

Good study practices are those that get the best results for you. Some suggestions for getting the most out of the book are included here, but, in the end, your study practices are what you make them.

As in almost any endeavor you undertake, a little planning will increase effectiveness. Begin by setting aside a part of each day for study. It doesn't have to be a long period of time; you will be surprised at the results that 20 minutes of concentrated study daily will produce. Once you are underway, work at it steadily. You are much better off studying a little bit often than studying a lot once in a while. As a matter of fact, you shouldn't try to absorb too much information at a time.

Then there is the matter of retaining what you have learned. There are paragraphs in this book which you will read several times because you can't retain all the information with a single reading. Make a point of summarizing what you have read, restating the information in your own words. It's also a good idea to take notes, especially when the going is difficult. Make a point of discussing what you have learned with other strikers, or with Radarman petty officers. It will help you fix ideas firmly in mind.

Use every opportunity to check what you have learned against equipment operation of your ship. If your ship lacks a particular piece of equipment, arrange to observe its operation on another ship. As an active duty Radarman or striker you will never be far from the major radar equipments used by the Navy. If you drill with the Reserve, your opportunities to work with the latest gear will be limited. In this case, make the best use of your annual active duty for training.

Test your progress by answering the questions at the end of each chapter. If there are any you can't answer correctly and with confidence, go over the textual matter again. If you are still puzzled by the material, ask the leading Radarman to explain it for you. He will be glad to square you away, for one of his prime duties is to help the Navy train good Radarmen.

CORRESPONDENCE COURSES

Follow the same plan for a correspondence course. You won't get very much from the course if you simply search through the text trying to answer each question as you come to it. Read and study the text, then answer the questions. After you have answered as many as you can, check your answers against the text, and proceed to review material for answers to the remaining questions.

OTHER OPPORTUNITIES

A great deal has been said about self-study and moving ahead on your own. Actually, in most instances, you will have the additional benefits of a shipboard training program, including instruction, lectures, demonstration, and on-the-job training. Opportunities to attend courses at the various Radarmen schools and fleet training centers are available to all Radarmen.

RADARMAN AND COMBAT READINESS

There are rewards in being a Radarman greater than the satisfaction of advancement and increased pay, although these are important. When your ship in peacetime gets an outstanding mark in her operational readiness inspection, you have had a big hand in it. Among other things, an outstanding mark means that the ship is in all respects ready for warfare and she has demonstrated this by detecting all attacks—surface and

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air—directed against the ship. It means that you have detected the various bogeys and raids, and tracked them though they tried evasive and deceptive means of escaping detection. You have the satisfaction of a job well done, and something more. It is an item called prestige and it means that you rate with your shipmates, and your ship rates with the squadron and task organization in which she operates.

In time of war, it is the Radarman who most often sounds the alert for combat. The GQ alarm brings men to their battle stations, but it is the Radarman's warning of a contact that sounds the GQ alarm. All of our vast arsenals of weapons and missiles are severely hampered in their use until the Radarman detects the enemy.

The Navy encourages ambitious men and provides many opportunities for self-improvement and advancement. There are men ahead of you who moved up with a letter of commendation in their records attesting to their proficiency as Radarmen. How well you do depends to a large degree on you. If you conscientiously apply yourself, you'll get those promotions. And if you have talent to spare, the door is wide open. You begin as a radar operator, and, one day, you are the leading PO, in charge of the CIC gang. You advance in rating to Chief and you continue to apply yourself. From Chief, you can advance to Senior Chief Radarman and Master Chief Radarman.

Another possibility for the ambitious Radarman is the Limited Duty Officer program. To become eligible you have to be a Chief or First Class PO and have at least 8 years' naval service. If selected, you will be commissioned an ensign with limited duty in operations. Don't wait until you have 7-1/2 years' service before you start your preparations. Dig in now! See your division officer and your I and E officer to get some help in planning a sound educational program. Advanced planning is necessary to success.

Good luck and smooth sailing!

QUIZ

1. What are the starting duties of a Radarman?
2. What is a rating?
3. What are rates?
4. How many rating groups in the Navy? What is the number and the name of the group to which Radarmen are assigned?
5. Aboard what type of ship will you spend the seagoing portion of your career as a Radarman?
6. In what book will you find your requirements for advancement?
7. Where will you find the military requirements for advancement?
8. What are the subdivisions into which professional requirements are separated?
9. What is NavPers 760, Record of Practical Factors?
10. What is your fleet examination based on?
11. What sections of NavPers 10052 should you read?
12. What is the purpose of this training course?

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CHAPTER 2

RADAR NOMENCLATURE

YOU AND ELECTRONICS

Electronics today is becoming increasingly important—in the home and in industry as well as in the military forces.

The military services' programs now invest millions of dollars annually in electronic research to provide improved equipments to increase the effectiveness of the armed forces. Through all of this research and development the operational concepts remain fairly consistent; we merely improve equipments and their utilization.

A well-rounded knowledge of the capabilities of present-day electronic equipments is essential to each Radarman if he is to be able and efficient in performing all duties to which assigned. To become a Radarman, you are not required to qualify as a specialist in electronics, but you must be familiar with the nomenclature, general scientific basis, and capabilities of equipment you operate.

NOMENCLATURE

Nomenclature designations are used primarily as the short title of equipments. These designations are unclassified, whereas the actual name of the equipment may sometimes be classified.

The nomenclature system used by the military services to identify electronic equipment and independent units that are not parts of specific equipment is called the Joint Electronics Type Designation System ("AN" system) for communication and electronic equipment.

The AN nomenclature is assigned to:

1. Complete sets of equipment and major components of military design.
2. Groups of articles of either commercial or military design which are grouped for a military purpose.
3. Major articles of military design which are not part of, or used with, a set.
4. Commercial articles when nomenclature will facilitate military identification or procedures.

AN nomenclature is not assigned to:

1. Articles cataloged commercially except when nomenclature will facilitate military identification or procedures.
2. Minor components of military design for which other adequate means of identification are available.
3. Small parts such as capacitors and resistors.
4. Articles having other adequate identification in American war standard or joint Army-Navy specifications.

EQUIPMENT INDICATOR LETTERS

Complete systems of equipments are designated by three indicator letters that follow AN/ and signify (1) kind of installation, (2) type of equipment, and (3) purpose. Using AN/APA-2 as an example, check the equipment indicator letters in table 2-1 to see if you can determine what AN/APA-2 is and where it may be used.

"AN" indicates the equipment was assigned the type number in the "AN" system. "A" of the indicator letters, as shown in the Installation column, means that the equipment is airborne, "P" in the Type of Equipment column signifies that the equipment is radar; and "A" in the Purpose column indicates that the equipment is an auxiliary assembly. The number 2 following the letters shows that it is the second model designed for airborne radar auxiliary assemblies. Any modifications to the equipment will be indicated by adding A, B, etc., after the model number.

ADDITIONAL INDICATORS

Additional indicators are used to identify training sets, experimental sets, and the organization associated with an experimental set. Parentheses are used when a need exists for a

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Table 2-1. —Equipment Indicator Letters.

Installation	Type of Equipment	Purpose
A—Airborne (installed and operated in aircraft) B—Underwater mobile, submarine C—Air transportable (inactivated; do not use) D—Pilotless carrier F—Fixed G—Ground, general ground use (includes two or more ground installations) K—Amphibious M—Ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment) P—Pack or portable (animal or man) S—Water surface craft T—Ground, transportable U—General utility (includes two or more general installation classes, airborne, shipboard, and ground) V—Ground, vehicular (installed in vehicle designed for functions other than carrying electronic equipment, etc., such as tank)	A—Invisible light, heat radiation B—Pigeon C—Carrier D—Radiac E—Nupac F—Photographic G—Telegraph or teletype I—Interphone or public address J—Electromechanical (not otherwise covered) K—Telemetering L—Countermeasures M—Meteorological N—Sound in air P—Radar Q—Sonar or underwater sound R—Radio S—Special types, magnetic, etc., or combinations of types T—Telephone (wire) V—Visual or visible light W—Armament (peculiar to armament, not otherwise covered) X—Facsimile or television	A—Auxiliary assemblies (not complete operating sets) B—Bombing C—Communications (receiving and/or transmitting) D—Direction finder G—Fire control or searchlight directing H—Recording (photographic, meteorological, or sound) L—Searchlight control (inactivated; use "G") M—Maintenance and test assemblies (including tools) N—Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach, and landing) P—Reproducing (photographic and/or sound) Q—Special, or combination of purposes R—Receiving, passive detecting S—Detecting and/or range and bearing T—Transmitting W—Control X—Identification and recognition

more specific identification than that provided by the nomenclature assigned to a specific design.

COMPONENT INDICATOR LETTERS

Independent major units that are not part of, or used with, specific sets have a type number that consists of a component indicator, a number, the slant, and such of the equipment indicator letters as apply. For example, the SB5/PT is the type number of a portable telephone switchboard for independent use. The component indicator letters in use can be found in *Electronics Maintenance Book*, NavShips 900,000.

NAVY MODEL SYSTEM

The assignment of Navy model letters to naval equipment depends on the primary function of the equipment, such as receiving, transmitting, direction finding, etc. Thus, the system is applicable to all radio, radar, and sonar equipments and, once learned, facilitates the recognition and identification of all Navy equipments.

Now that the AN system has been instituted, the Navy model letter system of designating equipment no longer is in primary use. However, there still are many equipments in the naval establishment with this type of designation.

With the exception of fire control radar, which was given a mark (or Mk) designation, the model designation of a Navy radar is intended to indicate in a general way the primary job of the gear. Older Navy equipment is designated as in table 2-2.

For example, the SC, SG, and SR are search radars. The second letter shows the approximate order in which the equipment was developed. Improved models of a particular set are designated as SG-1, SG-1B, SG-2, and SG-3. (Note,

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Table 2-2. —Navy Model System.

A	Airborne—used as a prefix to indicate airborne installations as: AR series—Airborne radio receiving, etc.
B	IFF.
CX	Commercial experimental.
D	Radio direction finding.
E	Emergency power.
FS	Frequency shift keying.
G	Formerly aircraft transmitting (now superseded by A series).
J	Sonar listening (receiving).
K	Sonar transmitting.
L	Precision calibrating.
M	Combined radio transmitting and receiving.
Mark	Fire control radar.
N	Sonar navigational aids, including echo sounding.
O	Measuring and operator training.
P	Automatic transmitting and receiving.
Q	Sonar ranging.
R	Radio receiving.
S	Search radar.
T	Radio transmitting (includes combination transmitting and receiving).
U	Remote control (includes automatic keyers).
V	Radar repeaters.
W	Combined sonar ranging and sounding.
X	Naval experimental.
Y	Navigational and landing aids.
Z	Navigational and landing aids (airborne)—superseded by model Y series.

In sonar equipment, the first letter indicates the general use of the equipment. The second letter of the Q series equipment designates the type of projector used as follows:

QA	Quartz steel.
QB	Rochelle salt.
QC	Magnetostriction.
QD	Depth determining (not Echo sounding).
QG	Magnetostriction—split-lobe type.

though, that the letter X is used ONLY to designate experimental equipment.)

COMMON ELECTRICAL AND ELECTRONIC TERMS

A knowledge of basic electricity is a requirement for a Radarman. Throughout your career as a Radarman you will come in contact with the common electrical and electronic terms such as volt, ohm, ampere, watt, etc. Here we will define commonly used terms without involving formulas and mathematics. (Quite often a formula is used for an explanation.)

Incorporation of these definitions in this text in no way relieves you of your responsibility to study *Basic Electricity*, NavPers 10086, and *Basic Electronics*, NavPers 10087.

THE STRUCTURE OF MATTER

The structure of matter is related so closely to electricity that neither can be understood without some knowledge of the other. MATTER is any substance that has weight and occupies space. All substances are composed of one or more basic materials called elements.

An ELEMENT is a substance that cannot be separated CHEMICALLY into other substances. Some well-known elements are hydrogen, oxygen, gold, silver, iron, copper, tin, and aluminum. The smallest particle into which an element can be divided without losing its identity is an ATOM.

A COMPOUND is a substance that consists of a chemical union of two or more elements. The physical and chemical properties of a compound are different from those of the elements that compose it. Some well-known compounds are table salt (sodium and chlorine), iron rust (iron and oxygen), and water (hydrogen and oxygen). The smallest particle into which a compound can be divided without losing its identify is a MOLECULE. In a compound, a molecule is composed of two or more atoms of different elements. For example, a water molecule is composed of 2 atoms of hydrogen and 1 atom of oxygen.

ELECTRON THEORY

The modern theory of the structure of the atom is the electron theory. According to this theory, each atom contains a number of positively charged particles called PROTONS, and an equal number of negatively charged particles called ELECTRONS. The atom also contains uncharged particles known as NEUTRONS.

The electron is the smallest, lightest particle of matter and is the smallest unit of negative charge. The proton is an elementary particle that has a unit positive charge, and contains most of the mass of the atom. The neutron is an uncharged particle that has approximately the same mass as the proton. There are other

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particles in the atom, but they are not important in the study of electricity.

All atoms of any element are similar in construction because they consist of electrons, protons, and neutrons. An atom of one element, however, differs from an atom of another element in the number of electrons and in the number of protons and neutrons in the nucleus or central portion. The number of protons in the central portion determines the quantity of charge there. The electrons of all the known kinds of atoms are alike.

All the protons and neutrons are concentrated in the nucleus of the atom. The electrons revolve about the nucleus in elliptical paths, or orbits. The atom is normally neutral—that is, the sum of the negative charges of the electrons is equal to the sum of the positive charges of the nucleus. If the atoms of a substance lose some of their electrons, or negative charges, the substance becomes positively charged. Likewise, if the atoms of a substance gain electrons, the substance becomes negatively charged. It is a fundamental principle of electricity that bodies having unlike charges attract one another and bodies having like charges repel one another. The force of attraction or repulsion between two charged bodies in air is proportional to the product of the charges and is inversely proportional to the square of the distance between them. Thus, the greater this distance, the weaker is the force. If the distance between charges is doubled, the force is decreased to one-fourth as much.

CONDUCTORS AND INSULATORS

The atoms of some metallic substances have electrons that are so loosely bound to their nuclei that a comparatively small force can cause them to move from one atom to the next. These electrons are called FREE ELECTRONS. Substances such as zinc, silver, aluminum, and copper, which have many loosely bound electrons, are called CONDUCTORS.

The atoms of nonmetallic substances have electrons so tightly bound to their nuclei that an exceedingly large force is required to tear them loose and cause them to drift to the next atom. Substances that have few free electrons such as glass, slate, mica, porcelain and rubber are called nonconductors, or INSULATORS.

UNITS OF MEASUREMENT

When a conductor has a difference in potential applied to its two ends, a flow of electrons (a CURRENT) occurs in that conductor. The unit for measuring electric current is the AMPERE, which expresses a rate of electron flow.

The standard current of 1 ampere is said to be flowing through a resistance of 1 ohm if there is 1 volt of potential difference across the resistor. One ampere also equals the flow of 1 coulomb per second. A coulomb is the quantity of electricity (6,280,000,000,000,000,000 electrons) moved by a current of 1 ampere in 1 second.

If the current is constant, the amperes can be multiplied by the elapsed time in seconds and the result is the total of coulombs of electric charge. For example, 1 ampere hour, which is 3600 coulombs, passes through a wire if 1 ampere flows for 1 hour.

HOW TO WRITE LARGE NUMBERS

Many units of measurement in electricity are expressed as small decimals or large whole numbers. For example, a farad, which is a unit of measurement of capacity, is so large that for most practical purposes only millionth parts are used. A prefix, MICRO, is used to denote a millionth part of a farad. Hence a microfarad equals 0.000001 farad. In addition, there are three other similar prefixes continually used: MILLI meaning thousandth (.001), KILO meaning 1 thousand (1000), and MEGA meaning 1 million (1,000,000).

You can readily see that if you had to use the above numbers in a formula, they would be extremely awkward and time-consuming, and spread out the problem over much space. Also, there is the chance of making errors when writing all the zeros required in most problems. Electronics men make use of the facts that algebra teaches about exponents and powers of 10, and thus reduce the labor of reading and writing large numbers and of computing with them.

A power of a number is the product obtained by multiplying the number by itself a given number of times. For example, $10 \times 10 = 100$ or 10^2; $10 \times 10 \times 10 = 1000$ or 10^3; and $10 \times 10 \times 10 \times 10 = 10{,}000$ or 10^4. The first product, 10^2, is spoken as 10 squared, and 10^3 as 10 cubed. However, 10^4, 10^5, etc., are spoken as 10 to the fourth power, 10 to the fifth power, and so on. The number 10 itself is 10^1. The 10 is the

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base and the small numerals 2, 3, 4, and so on are referred to as exponents. Thus, the exponent shows the number of times the base is multiplied by itself (multiply one less time than the exponent).

Conversely, number 1 is 10^0, 0.1 is 10^{-1} (10 to the negative power of 1), 0.01 is 10^{-2}.

To multiply LIKE EXPONENTIAL QUANTITIES, add the exponents. This rule will prove useful in solving many problems, particularly if you are working with very large numbers. If you want to multiply 10^{15} by 10^7, simply use the rule and the answer will be $10^{15+7} = 10^{22}$. These numbers are deceiving as to size because 10^{15} = 1,000,000,000,000,000. Look at the work saved by not having to write out the entire multiplication. Such large numbers are often used in electronics work, so you can see this is a time-saving rule.

To divide LIKE EXPONENTIAL QUANTITIES, subtract the exponents. Apply this rule if you encounter $\frac{10^3}{10^2}$ and you will have $10^{3-2} = 10^1$ which will be much easier to compute.

ELECTRIC CURRENT

Early scientists assumed the direction of flow of an electric current to be from a positively charged terminal to a negatively charged terminal. This conventional direction of current flow is still used in many present-day texts. The modern concept of the electron theory, however, is that electric current really consists of electrons moving through an external circuit from a negative to a positive terminal. Throughout this text the rules for polarity and direction of current flow are based on the modern theory.

Because the electric charges flowing in most circuits are free electrons, ELECTRIC CURRENT is now understood to be a flow of these electrons. Thus, when we talk of electric current, we mean electrons in motion.

When electrons flow in one direction only, the current is called a DIRECT CURRENT (D-C). A direct current is the movement of free electrons from atom to atom along the conductor. The electrons flow out of the negative terminal of the source, through the load, and back to the positive terminal. The circuit is completed through the source, and the direction of current is always one way in all parts of the circuit.

An ALTERNATING CURRENT (abbreviated A-C) consists of electrons that move first in one direction and then in the other. The direction of flow changes periodically. It is important to know the number of electrons that flow past a given point on a conductor in a certain length of time. If a coulomb flows past a certain point in 1 second, we call this amount 1 ampere of electrical current. Two coulombs each second would be 2 amperes. Therefore the unit of measurement of rate of flow of electric current is the AMPERE.

THE AMPERE

The practical unit of current is the ampere. You have read that the movement of electrons through a conductor results in what we know as electricity. An ampere of electric current is the movement of 6.28 billion billion electrons past a point in a single second. No one has ever counted them as they go by. The number has been determined mathematically. In practice, electric current is generally expressed in amperes because 1 ampere equals 1 coulomb per second.

You will use electrical meters called milliammeters which measure current in milliamperes. The prefix milli means a thousandth part. A milliampere is one-thousandth part of an ampere. Its abbreviation is ma. Since the current to be measured in radar is very small, the ampere is not a practical unit — hence milliammeters are used. The dial faces of all your milliammeters will contain whole numbers such as 5, 10, 25, etc. Remember that these numbers are not WHOLE amperes but are 5 thousandths, 10 thousandths, etc.

THE VOLT

Even though the electron is extremely small, energy is required to move one. In fact, force is needed to move anything. Naturally, when you move a heavy object, there must be a greater expenditure of energy than when you move a light one. It is more difficult to move an object rapidly than to move it slowly, and the farther you move the object, the more work you have to do.

The three factors—how heavy, how fast, and how far—hold true for moving electrons also. Electrons are small, but the energy required to move them depends on the number being moved, the speed of movement, and the distance moved. The push or energy used to move

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electrons from one place to another is known as VOLTAGE.

If the amount of push or energy is LARGE, the VOLTAGE IS SAID TO BE HIGH. If the push is SMALL, the VOLTAGE IS LOW. When the numbers on your voltmeter read 100 volts, 125 volts, and the like, they represent the actual amount of force required to move a definite number of electrons from one place to another. Volts are abbreviated V.

A difference in electric pressure is necessary to cause a current to flow between two points in a circuit. This difference in electric pressure is called ELECTROMOTIVE FORCE (EMF), or POTENTIAL DIFFERENCE. The practical unit of EMF is the volt. One volt is the pressure that is required to force a current of 1 ampere of current to flow through a conductor which has a resistance of 1 ohm.

A device that can maintain a potential difference is a source of EMF and develops a voltage. A potential can be developed (1) by chemical means, as in a primary or secondary cell; (2) by mechanical means, as in an electric generator; and (3) by heat, as in a thermocouple. When any one of these devices is operating with its terminals connected to a closed circuit, current flows through the circuit because the device maintains a potential difference at the terminals. The terms potential difference, EMF, and voltage often are used interchangeably. In an electric formula the capital letter E or the abbreviation EMF stands for electromotive force.

THE OHM

You have experienced FRICTION in its many forms. It serves to hold you back or to slow up your movements. The resistance to electrical movement is measured by the ohm. The symbol for the ohm is the Greek letter omega .

In an electrical formula, the capital letter R stands for resistance. The resistance which a substance offers to the flow of electric current depends upon a number of factors. These are:

1. The nature of the substance itself.
2. The length of the substance.
3. Cross section area of the substance. The greater the cross section area, the less the resistance.
4. Temperature of the substance.

WATT

A watt (W) is the unit of electrical power. Power is the rate at which energy is expended. In a direct current circuit the electrical pressure (volts) times the number of electrons flowing per second (amperes) equals the electrical power. Thus, a direct current of 5 amperes flowing at 10 volts D-C expends 50 watts of power.

INDUCTANCE

The property of a circuit which opposes any change in current flowing is called the inductance. Since this opposition is caused by voltages induced in the circuit itself by the changing magnetic field, anything that affects the amount of magnetic flux must also affect this inductance. (The magnetic field is made up of magnetic lines of force commonly called magnetic flux.)

The unit used to measure the inductance of a circuit is called the henry (H). A henry is defined as the inductance present when a current change of 1 ampere per second in a circuit produces an induced electromotive force of 1 volt.

It is often convenient to employ the millihenry (MH), which is one-thousandth of a henry, and the microhenry (μh), which is one-millionth of a henry.

INDUCTIVE REACTANCE

The opposition to the flow of current in an A-C circuit is a combination of the resistance of the conductor and the opposition of the self-induced voltage. The opposition created by inductors is inductive reactance. Since the current flowing through an inductive circuit must also overcome the circuit resistance, the total opposition to the flow of current will be the sum of the resistance and the reactance. Together these two oppositions form the impedance of the circuit. In a formula, capacitive reactance is represented by X_C and inductive reactance by X_L.

The inductive reactance of an inductor depends upon its inductance and the frequency of the current it is carrying. In each case, the higher the frequency and the larger the inductance, the greater the reactance will be.

CONDENSERS

A condenser is formed by two conductors separated from each other by some insulatory medium. Condensers are made in a variety of sizes and shapes to fit specific needs in radar.

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You'll run across a lot of them in your work as a Radarman. Some of the common types you will encounter are variable condensers, fixed variable condensers, paper condensers, electrolytic condensers, and mica condensers.

CAPACITANCE

By capacitance, we refer to the ability (or capacity) of a condenser to hold or store electric charges. The terms capacity and capacitance are often used interchangeably, but capacitance has a better defined meaning. Capacitance is the property of an electric circuit that opposes any change of voltage in the circuit. It differs from inductance, which opposes the movement of electrons in an electrical circuit. Capacitance also is defined as that property of a circuit in which energy may be stored in an electric field. Let us study the measurement of capacitance.

The unit for measuring the capacitance of a circuit is the farad (F), named in honor of the English scientist Faraday. The farad is the amount of capacitance present when 1 coulomb of electrical energy is stored in the dielectric field of a circuit with 1 volt of electromotive force applied.

For practical purposes, the farad is too large a value to be handled conveniently. We use the microfarad (μf), which is one-millionth of a farad, and the micromicrofarad ($\mu\mu$f), which is one-millionth of a microfarad.

CAPACITIVE REACTANCE

Like any other electrical device, a capacitor (or condenser) offers opposition to the flow of current. Since the capacitor acts as an open circuit to direct current, the opposition to the movement is not resistance but REACTANCE. The reactance of a capacitor depends upon its capacitance and the frequency of the current it is carrying. In each case, the higher the frequency and the larger the capacitance, the lower the reactance will be.

IMPEDANCE

The total opposition to the flow of alternating current in a circuit is called impedance. Since it is a measurement of the opposition to the flow of current, impedance has the same unit of measurement as resistance, that is, the ohm. The symbol representing impedance is Z. In a circuit composed of resistance, capacitance, and inductance, the total opposition to current flow is a combination of these three types of opposition. This combination is the impedance of the circuit.

MODULATION

Modulation is the process of altering the character of a continuous-wave radio-frequency signal in such a manner as to convey intelligence upon being demodulated (detected) in a radio receiver. There are two systems of modulation in general use, called amplitude modulation and frequency modulation.

Amplitude Modulation

Amplitude modulation (AM) is a continuous-wave, carrier signal that is caused to vary in amplitude in exact accordance with the shape of the audio-frequency signal of the intelligence it is desired to convey.

Frequency Modulation

The process of varying the frequency of an R-F carrier wave in accordance with the amplitude and frequency of an audio signal is called frequency modulation (FM). The intelligence to be transmitted is superimposed on the carrier in the form of changes in the frequency of the carrier. This type of modulation has certain inherent advantages over conventional AM transmission, particularly when high-quality, static-free transmission is required. Navy communications use a limited number of FM transmitters and receivers. Aircraft altimeters use frequency modulation, as do some radar and sonar equipments. The only contact a Radarman will have with frequency modulation will be to recognize it on an ECM panoramic adapter.

CYCLE

A cycle is one complete series of events at the end of which conditions are as they were at the starting point. Beginning with any particular phase or condition, one cycle is complete as soon as it starts repeating itself. (See figure 2-1.)

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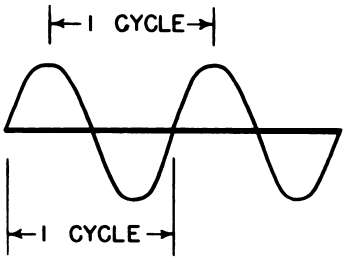

Figure 2-1.—The cycle.

FREQUENCY

In general, frequency indicates the number of times something occurs in a certain period of time. The frequency of eating, for example, is generally three times a day. The frequency of the human heart beat is about 72 beats per minute. Frequencies used in radio are measured in cycles per second (CPS), or the rate at which the cycles occur. (See table 2-3.)

Definite frequencies for radar cannot be revealed here. The tendency is to use wavelengths in and near the microwave band for radar. Equipment using microwaves has different operational characteristics from equipment having ultrahigh frequencies. As you learn to operate the various sets, these differences will become clear to you.

Since cycles occur regularly, a definite interval of time is required to complete each cycle and start repeating. This time interval is known as the PERIOD. Remember that it is a measure of the time required for 1 cycle to occur. It is reasonable to expect, therefore, that the period will decrease as the number of cycles per second increases.

If 1 second is divided into 100 equal parts, each part will be one-hundredth of a second long. The period is one-hundredth of a second when the frequency is 100 CPS. Now note this formula carefully:

Period = 1 ÷ frequency.

Another term that will simplify our presentation is WAVELENGTH. Wavelength is sometimes used to express radar frequencies and is the actual distance traveled by the energy while it is completing 1 cycle.

WAVELENGTHS

Wavelength merely means the distance between successive waves. When you drop a pebble in a pool, the waves that run outward are spaced a certain distance apart. In a shallow pool, you could measure the distance between the tops, or crests, of two waves. It might be 6 inches, or 1 foot, or even more. The distance between one wave, and the wave that follows or precedes it, is known as a wavelength.

We know that as long as we travel at a definite speed, we can cover a distance proportional to the time. In other words, if we travel at a speed of 30 knots for 1 hour, we go 30 nautical miles; if we travel for half an hour, we go only half as far. The distance increases with the time or, as expressed before, distance is proportional to the time. The distance we can go in a certain time is equal to the speed, or velocity, multiplied by the time. Radio energy, too, can travel a certain distance in a given period (that is, in a definite amount of time). This distance that radio energy travels in one period is called wavelength. It is a measureable distance and, by using the rule that distance equals velocity multiplied by time, we find that:

Wavelength (distance) =
velocity (speed) X period (time).

Usually, the period will not be known, therefore, a formula which gives the wavelength when the period is not known will be better for our purpose.

Table 2-3. —Frequencies Used in Radio.

Designation of radio waves according to frequency	Authorized abbreviations	Frequency in kilocycles per second
Very low	VLF	Below 30
Low	LF	30 to 300
Medium	MF	300 to 3000
High	HF	3000 to 30,000
Very high	VHF	30,000 to 300,000
Ultrahigh	UHF	300,000 to 3,000,000
Superhigh	SHF	3,000,000 to 30,000,000
Extremely high	EHF	30,000,000 to 300,000,000

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Remember that the period equals 1 divided by frequency. Substituting $1 \div F$ for P, the new formula will read: Wavelength = velocity X $1 \div$ frequency, or $W = V \div F$. The symbol for wavelength is λ, the Greek letter lambda. So the formula could be $\lambda = V \div F$.

Radar energy travels at a velocity of 162,000 nautical miles per second. If frequency is 2000 CPS, the period and wavelength can be determined as follows (F is frequency and μs microseconds):

Period = $1 \div F = 1 \div 2000$ second = $1{,}000{,}000 \div 2000\ \mu s = 500 \mu s$.

NOTE.—One second equals 1,000,000 microseconds.

Wavelength = $V \div F = 162{,}000 \div 2000$ = 81 nautical miles.

Thus we see that the energy travels 81 nautical miles while it goes through 1 cycle.

Nautical Mile

A nautical mile is 6080.27 feet (as contrasted with statute or land mile, 5280 feet), the length of 1 minute of arc at the equator. (The Navy uses 6000 feet or 2000 yards for all gunnery, navigation, and radar applications.)

Previously you were using large numbers, such as 1,000,000 and 2000. All those zeros make the numbers clumsy to work with. If you asked to help unload a cargo of 30-caliber ammunition, you would not be expected to pick up only 1 cartridge at a time. You would pick up a box containing 1000 cartridges. When asked how many you had stowed in a particular magazine, your answer would be given in number of boxes, not the actual number of individual 30-caliber cartridges.

You deal exactly the same way with individual cycles. True enough, it is impossible to store cycles in magazines, but you can give your answer in "groups" or "boxes" of cycles. The number of cycles in each group is 1,000,000 and the unit, or group, is called a megacycle.

If the frequency of a radar oscillator is 2,000,000 cycles, there will be 2 units of 1,000,000 each, that is, 2 megacycles. If the oscillator's frequency is 1,000,000,000 cycles, there are 1000 units of 1,000,000 cycles each. Thus, for common usage, as well as ease in writing, the frequency of radar oscillators is given in megacycles, abbreviated MC.

The simple units of electrical measure—volts, amperes, ohms, and watts—prove to be clumsy also when very large or extremely small quantities are involved. A system of prefixes has been developed for use in measuring large and small quantities of electrical units. The table below gives the common prefixes used in electricity. Each prefix can be used with any of the electrical units. For example, instead of saying "a 1,000,000-watt radar," it is handier to say "a 1-MEGAWATT radar." Instead of writting "0.010 amperes," it is easier to write "10 MILLIAMPERES." In testing insulation you will use MEGOHMS instead of millions of ohms. In radar work, the MICRO- and MILLI- prefixes are constantly used.

Mega	MILLION (1,000,000)
Kilo.	THOUSAND (1000)
Milli	One-THOUSANDTH (1/1000)
Micro	One-MILLIONTH (1/1,000,000)

QUIZ

1. What is the primary use of nomenclature designations?
2. What was the nomenclature called before the merger of the services?
3. What good does it do to learn the Navy model system?
4. What unit is used for measuring the quantity of electrical charge?
5. Who pointed out that an electrical current is a drift of free electrons through a conductor?
6. The unit of measuring the rate of flow of electric current is called the _____.
7. In an electrical formula, what does the capital letter R stand for?
8. Define the volt.
9. The unit of electrical power is the _____.
10. One complete series of events, at the end of which conditions are as they were at the starting point, is called the _____.
11. Radio energy can travel a certain distance in a given period. This distance is called _____.
12. How many nautical miles does radar energy travel in 1 second?
13. How would you write 300,000,000 cycles?

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CHAPTER 3

RADAR OPERATION AND METHODS

PRINCIPLES OF OPERATION

During the early days of World War II people heard about a "magic eye," a mysterious new device that could pierce darkness, fog, rain, sleet, and snow to give not only a warning but also an actual picture of approaching enemy ships and aircraft. It was rumored that distant shore lines, landmarks, and aids (as well as menaces) to navigation could be picked up by the "eye" and thrown upon a viewing screen.

The mystery proved to be no magic at all; it was simply a special application of radio principles that had been known to scientists for years. The new application was called RADAR. Radar is a method of using radio waves to detect the presence of all objects—surface craft, aircraft, or missiles, friendly or enemy. Radar allows you to SEE those ships or planes, to SEE their range and direction, and to SEE whether they are friendly or enemy. Radar means RAdio Detection And Ranging. If you understand that high-frequency radio waves are reflected like echoes from distant ships, planes, and missiles you are ready to learn about radar.

Radar is composed of a directional antenna system, a transmitter-receiver combination, an indicator, modulation generator or keyer, T - R (transmit-receive) box or duplexer, timer, and several other devices to control and supply power to the basic elements.

The antennas are of several sizes and shapes, depending on their application. Regardless of their shape or size, antennas are used for both transmitting and receiving.

In addition to indicating presence of objects, radar can determine bearing, distance, and elevation; and enables the operator to recognize the general characteristics of the objects.

The basic principles upon which its functioning depends are relatively simple. The seemingly complicated series of electrical events found in radar can be resolved into a logical series of functions which, when taken individually, may be easily identified and understood.

The radar transmitter, when turned on or keyed by the keyer or modulation generator, generates the ultrahigh frequency radio energy pulses, with sufficient power to excite the antenna. The time between each pulse of energy is always somewhat greater than the time required for the waves to make a round trip to the target and back. The returning echo is picked up by the antenna, then amplified by the receiver to give it enough strength to start the indicator.

A timer synchronizes the entire system. It tells the keyer when to turn on the transmitter and, at the same time, the indicator receives a synchronizing voltage from the transmitter to start recording the time interval between transmission and echo. In other words, the timer triggers the keyer and indicator at the same instant, and at regular intervals.

Since the receiver would become damaged with the large amount of power released by the transmitter each time a pulse is sent out, it is necessary to disconnect the receiver temporarily. A special automatic switch of many names—such as T-R box, reprod, duplexer—disconnects the receiver during the transmitting period, and reconnects it during the resting or "listening" period.

SOUND WAVE REFLECTION

The principle upon which radar operates is very similar to the principle of sound wave or echo reflection. If you shout in the direction of a cliff, or some other sound-reflecting surface, you will hear your shout "return" from the direction of the cliff. What actually takes place is that the sound waves generated by the shout travel through air until they strike the cliff. There they are reflected or "bounced off" and some are returned to the originating spot, where you then are able to hear the echo. Some time goes by between the instant the sound leaves and

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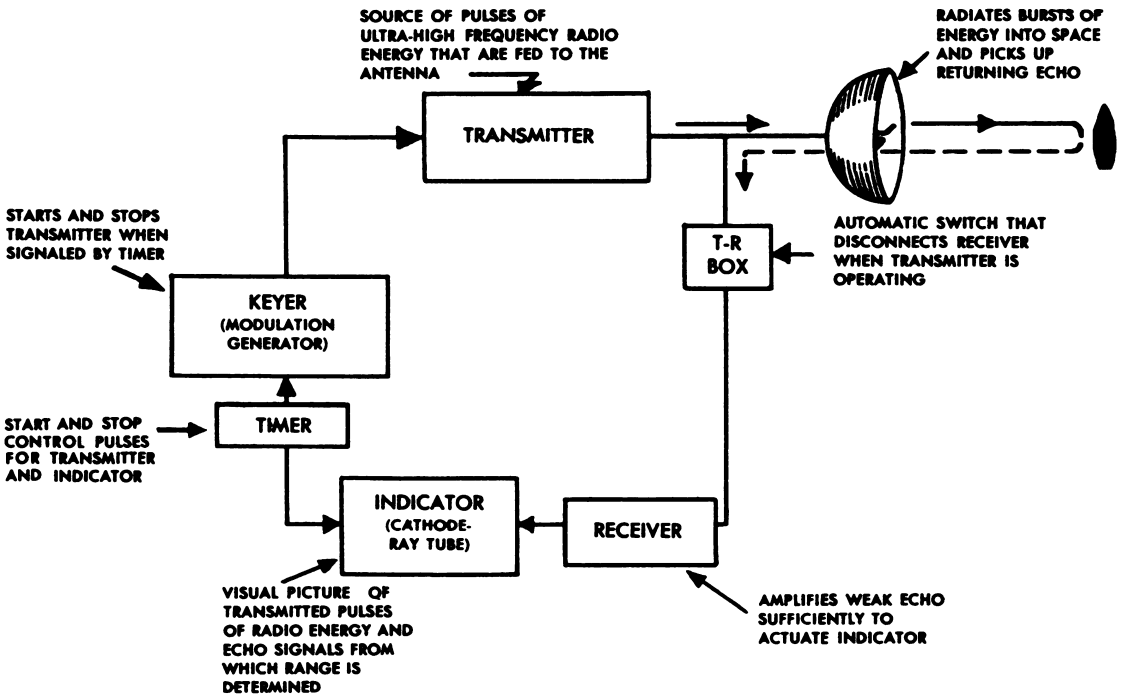
SOURCE OF PULSES OF ULTRA-HIGH FREQUENCY RADIO ENERGY THAT ARE FED TO THE ANTENNA
TRANSMITTER
RADIATES BURSTS OF ENERGY INTO SPACE AND PICKS UP RETURNING ECHO
STARTS AND STOPS TRANSMITTER WHEN SIGNALED BY TIMER
KEYER (MODULATION GENERATOR)
T-R BOX
AUTOMATIC SWITCH THAT DISCONNECTS RECEIVER WHEN TRANSMITTER IS OPERATING
START AND STOP CONTROL PULSES FOR TRANSMITTER AND INDICATOR
TIMER
INDICATOR (CATHODE-RAY TUBE)
RECEIVER
VISUAL PICTURE OF TRANSMITTED PULSES OF RADIO ENERGY AND ECHO SIGNALS FROM WHICH RANGE IS DETERMINED
AMPLIFIES WEAK ECHO SUFFICIENTLY TO ACTUATE INDICATOR

Figure 3-1.—Block diagram of basic elements of a radar system.

the time the echo is heard because sound waves travel through air at about 1100 feet per second. The farther you are from the cliff, the longer this time interval will be. If you were 2200 feet from the cliff when you shouted, about 4 seconds will pass before you hear the echo—that is, 2 seconds for the sound waves to reach the cliff and 2 seconds for them to return.

If a directional device, such as that shown in part A of figure 3-2, is built to transmit and receive sound, the principles of echo, together with a knowledge of the velocity of sound, can be used to determine the direction, distance, and the height of a cliff.

A sound transmitter, which can generate pulses of sound energy, is so placed at the focus of a reflector that it radiates a beam of sound. The sound receiver is a highly directional microphone located inside a reflector (at its focal point, and facing the reflector) to increase the directional effect. The microphone is connected through an amplifier to a loudspeaker.

The focal point is determined mathematically and can be compared to a flashlight with reflector and bulb. The directivity of the beam depends on the shape of the reflector and the bulb's focal point. If the bulb is placed a correct distance from the reflector, the light rays will be reflected outward in a narrow parallel beam. Should the bulb be placed a short distance outside the focal point the rays would come together at a point some place in front of the reflector. If the bulb is placed slightly closer to the reflector, the beam spreads. You will learn more about this when you study chapter 5.

After the microphone is connected through an amplifier to a loudspeaker, to determine the distance and direction of the cliff, the transmitting and receiving apparatuses are so placed that the line of travel of the transmitted sound beam and the received echo will be very nearly the same. They would be exactly the same if the same reflector could be used for both transmitting and receiving, as is done in radar. The sound apparatuses (both the transmitter and receiver) are rotated until the maximum volume of echo is obtained. The horizontal distance to the cliff is then determined by multiplying one-half of the elapsed time in seconds by the velocity of sound. This will be essentially the distance along the line RA (fig. 3-2, view A). If the receiver has a circular scale, marked off in degrees and properly oriented with a compass, the direction or azimuth of the cliff is also shown. Thus, if the angle indicated on the scale is 45°, the cliff is northeast from the receiver.

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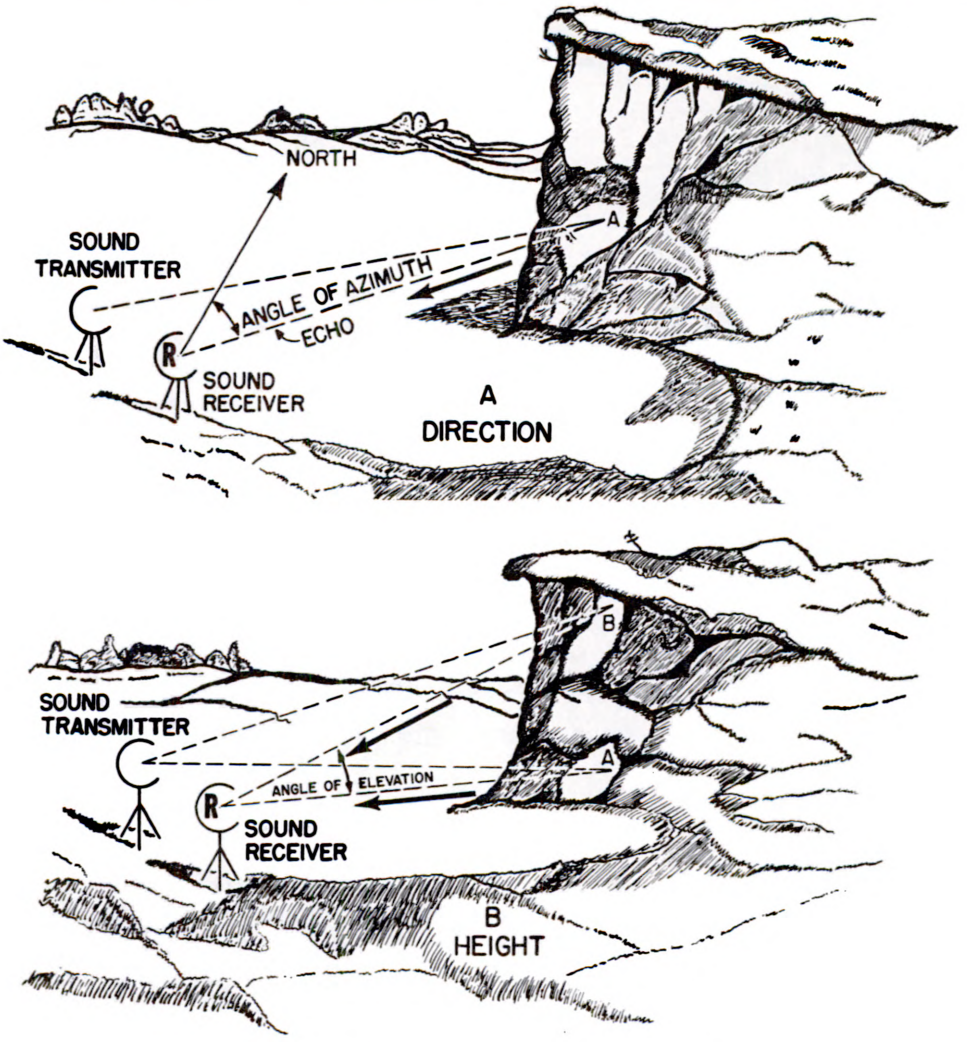

Figure 3-2.—Determination of direction and height.

To determine height (view B, fig. 3-2), the transmitter and receiver antennas are tilted from the horizontal position (shown by the dotted lines) while still pointing in the same direction. At first the echo still is heard, but the elapsed time is increased slightly. As the angle of elevation increases gradually, an angle is found where the echo disappears. This is the angle at which the sound is passing over the top of the cliff and is therefore not reflected back to the receiver. The angle at which the echo just disappears is such that the apparatus is pointing along solid line RB. If the receiver is equipped with a scale that permits a determination of the angle of elevation, the height of the cliff, AB, can be calculated from the angle and either the distance RA or RB, by the use of the basic trigonometric ratios.

RADIO WAVE REFLECTION

All radar sets work on a principle very much like that described for sound waves. In radar sets, a radio wave of extremely high frequency is used. The energy sent out by a radar set is similar to that sent out by an ordinary radio transmitter. (See fig. 3-3.)

The radar set has one outstanding characteristic different from a radio in that it picks up its own signals. It transmits a short pulse and receives its echo, then transmits another pulse and receives its echo. This out-and-back cycle

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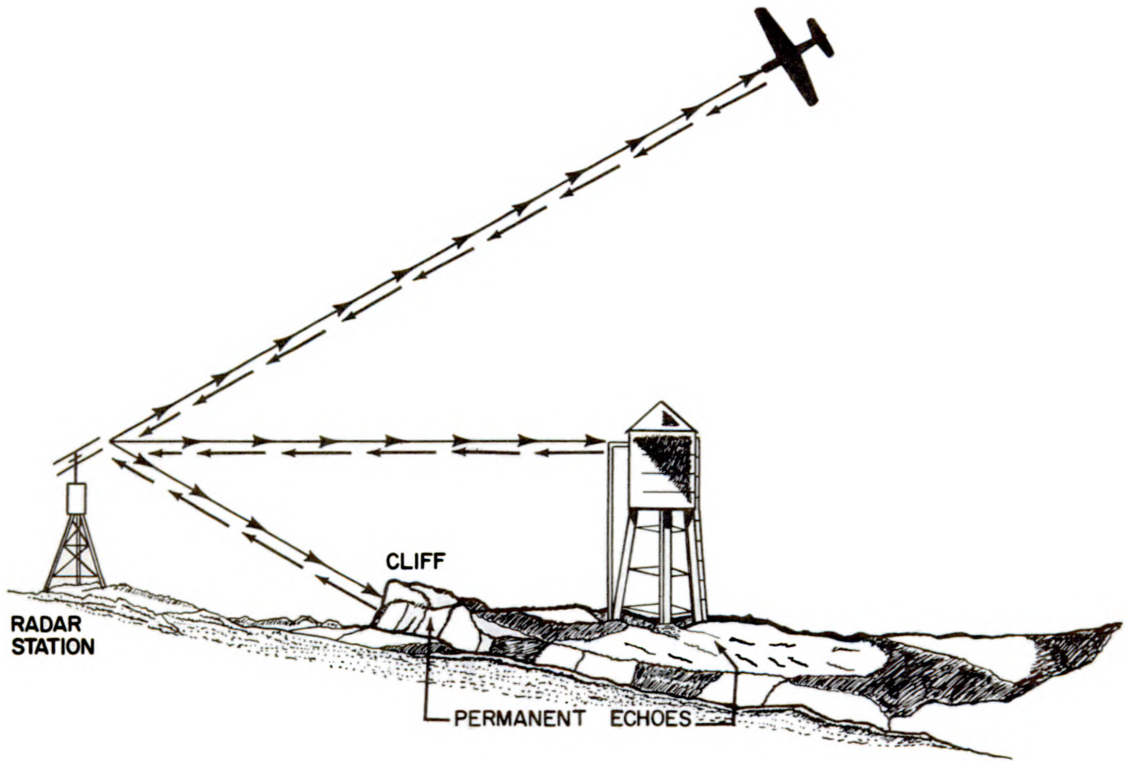

Figure 3-3.—Transmission and reflection of radar pulses.

is repeated 60 to 4000 times per second, depending on the design of the set. This repetition is often referred to as pulse repetition rate (PRR), pulse recurrence rate, or pulse repetition frequency (PRF). If the outgoing wave is sent into clear space, no energy is reflected back to the receiver. The wave and energy that it carries simply travel out into space and are lost for all practical purposes.

If, however, the wave strikes an object such as an airplane (fig. 3-3), a ship, building, or a hill, some of the energy is sent back as a reflected wave. If the object is a good conductor of electricity and is large compared to a quarter wavelength of the transmitted energy, a strong echo (but only a very small fraction of the transmitted energy) is returned to the antenna. If the object is a poor conductor or is small, the reflected energy is small and the echo is weak.

Radio waves travel at the speed of light, about 186,000 statute miles, 162,000 nautical miles per second, 300,000,000 meters per second, or 328 yards per microsecond. You have to admit that is pretty fast.

Accordingly, there will be an extremely short time interval between sending the pulse and receiving its echo. It is possible, however, to measure the interval of elapsed time between the transmitted and received pulse with great accuracy. The forming, timing, and presentation of radar pulses are accomplished by a number of special circuits and devices.

The directional antennas employed by radar equipment transmit and receive energy in a sharply defined beam. Therefore, when a signal is picked up, the antenna can be rotated until the received signal is maximum. The direction of the target is then determined by the position of the antenna.

The echoes received by the radar receiver appear as marks of light on an oscilloscope, a device similar to a TV screen and called scope for short. These marks are known as pips. The scope may be marked with a scale of miles, yards, or degrees, or a combination of miles and yards. Hence, from the position of a signal echo on the scope, an observer can tell the range and bearing, and sometimes the altitude, of the corresponding target.

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ELECTRON TUBES

In your studies of electronics and electricity you will find that electron tubes are of many types and designations and perform many functions. They can be made to (1) convert currents and voltages from one waveform to another, (2) amplify weak signals with minimum distortion, and (3) generate frequencies much higher than any conventional A-C generator.

As a Radarman you are required to know the functions, physical structure, and operating principles of the electron tubes. It is not our intent to go into detail here about the many and varied types of electron tubes. However, so that you will have a clearer understanding of the cathode ray tube, we will discuss briefly the diode and triode types of electron tube. See *Basic Electronics*, NavPers 10087, for a more detailed explanation.

The Start

In the year 1883, Thomas A. Edison almost discovered how the vacuum tube worked. In his experiments with the light bulb, he was troubled by the repeated breaking of the fragile carbon filament. To give the filament more strength, he placed supporting wires alongside, but not touching, the filament. A small piece of insulation provided the bracing link.

One day, Edison attached the positive terminal of a battery to the supporting wire and the negative terminal to the filament circuit. To his surprise, he saw that a current was flowing out of the bulb through the supporting wire. This was not according to the rules, since there was no conductor connecting the filament and the wire. Because he did not understand that current represents the flow of electrons, he wrote in his notebook:

> "When the positive terminal of a battery is connected to the supporting wire, a current seems to flow. This is an INTERESTING but WORTHLESS observation."

Interesting but worthless? In this case the observation paid dividends—but years later. In 1904, J. Ambrose Fleming, an English scientist who understood the flow of electrons, started to experiment with Edison's "worthless" observation.

He replaced the supporting wires with a large metal plate. With this new tube he conducted many experiments, the results of which are summed up in the following statements:

1. When a filament is heated until it is red hot, electrons will be given out by the metal and will form a cloud about the filament.
2. When a positive potential is placed upon the plate, these electrons will flow from the filament to the plate. By placing larger voltages on the plate, the rate of flow can be increased up to a certain point, beyond which no additional current can be made to flow.
3. If a negative potential is placed upon the plate, no current will flow in either direction.

Because Fleming discovered that current could flow only in one direction, this type of vacuum tube became known as Fleming's valve or "diode" (di- means two; ode means pole). The English vacuum tube is still called a valve.

The diode depends upon the principle that alternating current passed through the valve (tube) is changed to direct current because only during the positive half of an alternating current cycle are the electrons attracted from filament to plate.

Back in the United States, Lee De Forest conducted an experiment in 1907 that had been suggested by Fleming. De Forest placed a screen of fine wire between the filament and the plate. He found that when these wires were made more negative than the filament, the flow of electrons to the plate was reduced. If the screen was made more and more negative, the flow was reduced still further. If the screen was made sufficiently negative, the flow was stopped completely. The wires of this screen were wound on a frame so that they resembled the yard markers on a gridiron. For that reason the screen is called a GRID. This type of vacuum is called the "triode" (a three-electrode tube containing filament, grid, and plate). Using the grid in a vacuum tube to control the flow of current from the filament to the plate proved to be an important discovery. The grid permits a feeble voltage to control powerful machines.

Regardless of the number of elements included within a single glass envelope, every vacuum tube goes back to the principle discovered in Edison's "worthless" observations: Electrons are given off by a hot metal filament.

To understand vacuum tubes, a knowledge of electrons is essential. The properties of electrons are reviewed in the following section.

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All matter or substance consists of various combinations of atoms. Atoms consist of positive nuclei with various numbers of electrons revolving and vibrating around these positive nuclei. The solar system, with the planets revolving around the sun, is similar in arrangement to that of some atoms. The farther an electron in its vibrations gets from its positive nucleus, the less the attraction and the easier the electron can be pulled away to a nearby atom. All electrons are alike. They are always negative charges of electricity, whether in an atom of gold, copper, hydrogen, oxygen, or any other substance.

Electric potential (voltage) causes the electrons to be pulled along the conductor from one atom to another, from negative to positive. This movement of electrons causes the conductor to heat. The greater the potential, the greater the current and the greater the heat. The higher the temperature, the greater the speed with which the electrons revolve and vibrate.

As the current (heat) in a conductor is increased, the speed of the electrons reaches the point where they will leave the surface of the conductor. This is similar to heating water until it boils, causing steam to rise. The conductor must be heated until the electrons have a vibrating speed of around 620 miles per second before they leave the filament.

The whole foundation of electricity is based upon the electron, a very small, negatively charged particle. Atoms, of which all matter is composed, consist of a positively charged nucleus around which are grouped a number of electrons. The physical properties of any material depend upon the number of electrons and the size of the nucleus. In all matter there are a certain number of free electrons. The movement of these free electrons is known as a current of electricity. If the movement is in one direction only, the current, as you know, is direct (D-C). If, however, the source of voltage is alternated between positive and negative, the flow of electrons will likewise alternate. This, of course, is known as alternating current (A-C).

If metals, or metallic substances such as metallic oxides, are heated to a high temperature either by flame or by passing current through them, they have the property of throwing off, or emitting, electrons. The emitter is called the cathode.

Two types of cathodes or emitters are used in radio tubes. In one, known as the filament or directly heated type, the heating current is passed through the cathode itself. In the other, known as the indirectly heated type, the current is passed through a heating element, which in turn heats the cathode to a temperature sufficiently high for electron emission. In the indirectly heated type, the cathode is an oxide-coated metal sleeve placed over the heater element.

If the cathode is heated to a high temperature in the open air, it will burn up because of the presence of oxygen in the air. For this reason the cathode is placed in a glass or metal bulb from which all air has been removed. Such a space is known as a vacuum. Because it is difficult to heat an element in a vacuum tube by fire or flame, the cathode, which is in the form of a filament, is directly heated by passing a current through it.

Any isolated, positively charged body in the vicinity of the electron emitter will attract the negatively charged electrons. The positive charge on the body will soon be canceled by the electron attracted to it unless some means is employed to remove the electrons as fast as they arrive. This is done by connecting a source of constant voltage between the positively charged body and the electron emitter (fig. 3-4). This is the general arrangement in a two-element tube, or diode. It is also the basis of operation of all types of vacuum tubes.

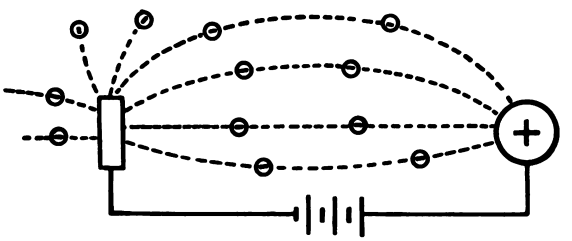

Figure 3-4.—Emitted electrons attracted by a positively charged body.

The higher the temperature of the cathode, the more electrons it will emit. However, if too much voltage is applied to a cathode, the heavy current flow will cause the filament or heater to burn out. The safe filament or heater voltage is determined by the manufacturer, and this voltage rating must be observed for satisfactory operation. The cathode of a tube will not continue to emit electrons indefinitely. After several

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thousand hours of operation, the number of electrons emitted will gradually decrease, until finally an insufficient number is emitted for proper operation. The decrease in emission capacity is due to the chemical change which takes place in the cathode. This is one of the reasons why tubes wear out.

Physical Structure

All electron tubes operate by controlling the flow of electrons through a confined space. The outer enclosure in which the electron flow occurs is called the ENVELOPE, and the source of free electrons is called the EMITTER or CATHODE. The element within the envelope toward which the free electrons are attracted is called the ANODE or PLATE. (See fig. 3-5.)

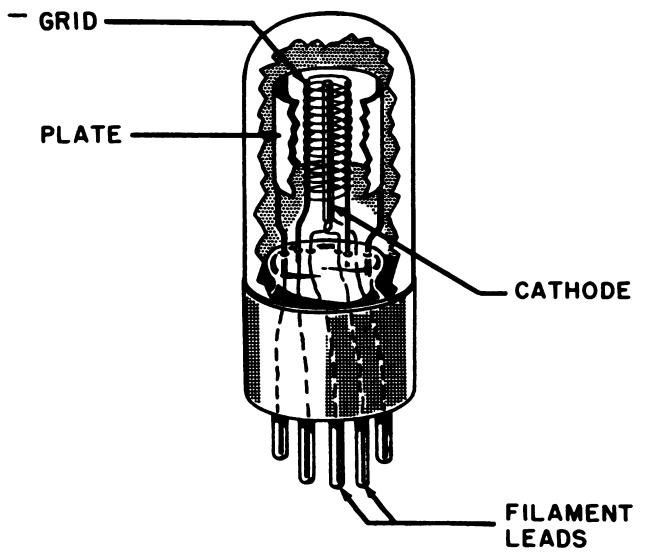

Figure 3-5.—Typical triode.

The outer walls of an electron tube are made either of thin glass or metal. The larger the tube, the thicker the wall must be because of the greater weight of the atmosphere on the tube. A tube's physical size is determined by performance function, and by designed equipment space in which the electron tube is to be used.

Air is evacuated from a tube for two reasons: (1) to prevent destruction of the cathode and heating element by oxidation or burning, and (2) to allow the flow of current from cathode to plate without colliding with gas particles. The lightest gas particle is about 1800 times as heavy as an electron. Thus a gas molecule would divert an electron upon impact and make the current flow erratic.

Metal tubes are designed to act as a shielded unit (the same as a glass tube with an external shield placed over it).

The shield on the tube acts primarily to prevent the introduction of stray fields within the envelope where induced voltages might be amplified many times, causing distortion in the output stages. There are a few circuits in electronic equipments where metal and glass tubes cannot be interchanged. Before making any interchanges, always check the tube manual.

The spacing of the electrodes in a tube is dependent on many factors but the two most important are frequency use and voltages between the electrodes.

The anode (plate) (fig. 3-6) is made of materials that will not emit electrons by thermionic ("boiling off") means at normal tube operating temperatures. Metals used as plates include iron, nickel, carbon, and tantalum. The plate is mounted externally with respect to the cathode. It is electrically insulated from the cathode and usually surrounds it in order to receive all of the cathode field emission. The plate usually has a dark surface to radiate the heat caused by the plate current.

Electron tubes are identified by a number or a combination of numbers and letters. So many different types of tubes have been introduced that it has become impossible to stick rigidly to the system as it was first set up. Some of the ideas contained in the original system have been followed for many years, however. In the old system, the type number is divided into four parts. First, a number consisting of one or more digits designates the filament or heater voltage. Second, one or more letters designate the type or function of the tube. Third, a number designates the number of useful elements in the tube. Fourth, one or more letters designate the size or construction. For example, the 6SK7 electron tube is a pentode having a filament voltage of approximately 6 volts and featuring single-ended construction (no grid cap) and interlead shields. Because thousands of different types of receiving tubes are manufactured, there are probably more exceptions to this system of designation than there are tubes that follow it completely. It is therefore desirable to refer to a tube manual when a tube characteristic is in question.

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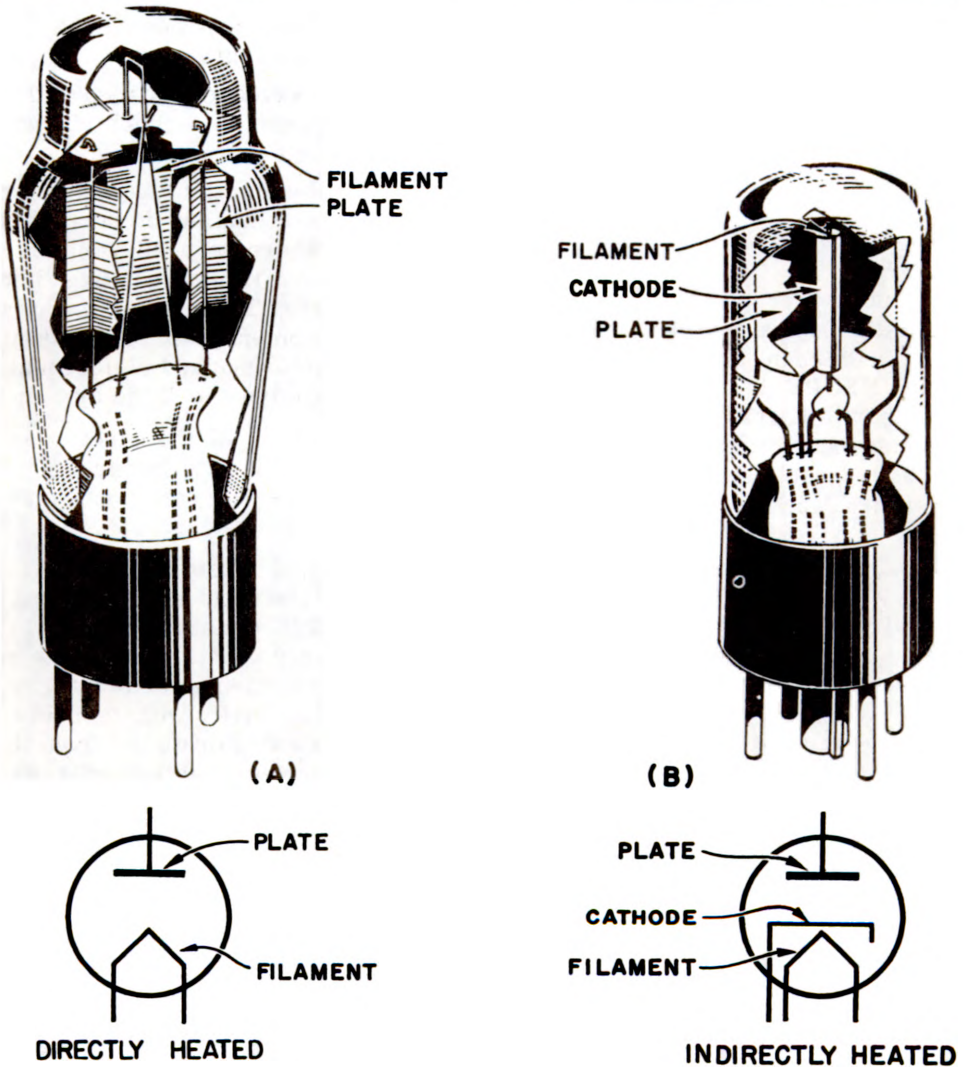

Figure 3-6.—Cutaway of 2-element tubes.

Types of Vacuum Tubes

There are many different types of vacuum tubes in everyday use. As stated before, no attempt will be made to explain them here; consult *Basic Electronics*, NavPers 10087, for further information. But inasmuch as the CATHODE RAY TUBE is one of the tools you will be working with, the ELECTROSTATIC and ELECTROMAGNETIC types will be explained here.

Every job, civilian or naval, has special tools to work with. One of a Radarman's most valuable tools will be the cathode ray tube (CRT). Without it radar has no practical use. Your understanding of the CRT and skill in using it, along with the radar, will determine to a large extent how well you do your job and how fast you get ahead in the Navy. Figure 3-7 shows a cutaway of the cathode ray tube, indicating the location of its principal components.

The heart of every indicator, as with home television receivers, is the CRT, a special type of vacuum tube. An indicator is a device that presents data in observable form. These data are composed of output signals from the radar receiver, the antenna positioning devices, the gyrocompass, and other units of the radar system.

Information displayed on the indicator is called the display, indication, or presentation.

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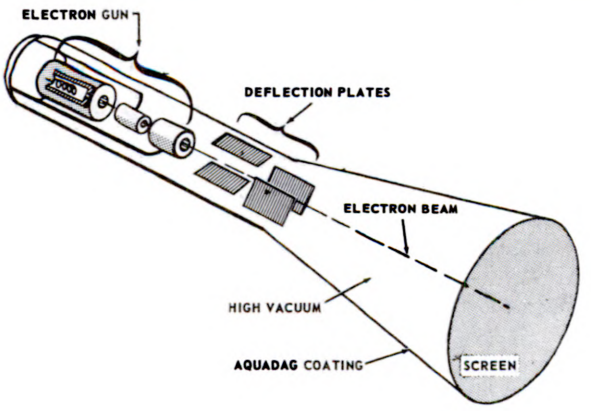

Figure 3-7.—The electrostatic cathode ray tube.

The cathode ray tube is called the indicator, indicator tube, display tube, CRT, or scope. Hereafter we will refer to it as the CRT.

Functions of the CRT

The cathode ray tube has the following purposes or functions:

1. To create a beam of rapidly moving electrons.
2. To control the intensity of this electron beam.
3. To focus the beam on a screen which will give off light at the point where the screen is struck by the beam.
4. To provide a means for moving the beam across the screen so that an image may be formed, thereby enabling you to view what the radar has detected so you can determine the bearing, range, nature, number, size, and altitude of any object.

Construction of the CRT

Construction of the CRT is quite simple. An electron gun accomplishes the first three purposes of the tube—creating an electron beam, controlling its intensity (brightness), and focusing it on the screen. A set of four deflection plates accomplishes the other purpose—when electrically charged, these plates provide a means for moving the electron beam across the screen so that an image may be formed. In addition to the electron gun and the set of deflection plates, a glass container encloses the electron gun and deflection plates in a vacuum. One end of the glass container or tube has deposited upon it a thin film of fluorescent material which glows for a short time at whatever place it is struck by the electron beam. It is upon this screen that the visible images are formed. The other end of the glass tube has a socket or base by means of which electrical connection can be made to the electron gun and the deflection plates.

Classification

All CRT's may be classified in accordance with the following points:

1. High vacuum or gas-filled.
2. Type of deflection—electrostatic or electromagnetic.
3. Size (diameter of screen).
4. Color of trace.
5. Persistence of screen (length of time the screen continues to give off light after the electron beam strikes it).
6. Deflection sensitivity expressed in volts per inch.
7. Type of focusing—electrostatic or electromagnetic.

Operation of the CRT

It is well at this point to recall the four important functions of the CRT: (1) to create a stream of electrons; (2) to control the strength of the electron stream, that is, to increase or decrease the number of electrons in the stream; (3) to accelerate the electron beam; and (4) to focus the electrons on the fluorescent screen of the CRT.

How the Electron Beam is Created

The cathode of the CRT differs from the types found in other vacuum tubes mainly in that its emissive properties must be restricted to the narrow cross-sectional area at the end of the cathode. The cathode itself consists of a metal thimble (about the size of the lead in a pencil), the front end of which is concave and coated with thorium or a similar chemical substance to increase its emissive properties. Within the metal thimble the heating element is turned on, then the cathode emits free electrons. A certain fraction of these depending on the intensity desired, are used in forming the electron beam.

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How the Electron Beam is Formed

Before the free electrons can be of any use, they must be concentrated into a narrow beam and sped toward the screen so that they all hit the screen hard enough to make it give off visible light. The spot where the electron beam hits the screen must be small and sharply defined so that the "picture" formed by the moving of the bright spot will be sharp and clear.

Remember that electrons are tiny negative charges and therefore they can be attracted by a body which is positively charged. The strength of this attraction is increased as the voltage difference between the cathode and this positively (or less negatively) charged body or anode is increased. In present-day CRT's, the less negatively charged body or anode is made up of two separate parts, each consisting of a metal tube with internal shields to stop all electrons that are not traveling in the main beam. The cathode is kept at a high negative voltage (approximately 1000 volts) and the second anode is at 0 volts, making the second anode have the effect of a positively charged body. The first anode is kept at a voltage which is less negative than the cathode by several hundred volts, and therefore, it attracts electrons as though it were positively charged to several hundred volts.

How the Brightness is Controlled

Now that there is a means of forming an electron beam and directing it toward the screen, there must be some method by which the brightness of the spot on the screen may be controlled. This can be done by varying the number of electrons in the beam. If many electrons, there will be a bright spot; if few electrons, a dim spot. To accomplish this, a shield with a hole in it is placed between the cathode and the anode. This new element, called the grid, resembles a tiny cup with a small hole in the bottom. Since the grid is very close to the cathode, it tends to exert a greater influence than the anodes on the electron cloud around the end of the cathode. If the grid is quite a bit more negative than the cathode, the attracting effect of the anode will be canceled and all of the electrons repelled back to the cathode. No electrons would enter the electron beam, and there would be no spot on the screen. If the grid is made less negative with respect to the cathode, some of the faster-moving electrons from the electron cloud at the end of the cathode will be able to overcome the repelling force of the negative grid and go through the grid hole and be attracted by the anode. There would be few electrons to form the electron beam and a dim spot would appear on the screen. To get a brighter spot, the grid is made less and less negative than the cathode. When the cathode and grid are both at the same voltage, nearly all of the electrons enter the electron beam and the spot on the screen becomes very bright.

There is a control on the front panel of the indicator which adjusts the grid voltage of the CRT and thereby controls the brightness of the spot. This control is usually labeled INTENSITY.

In an ordinary vacuum tube, such as a triode, the current through the tube, or what amounts to the same thing—the electrons flow from the cathode to the plate—depends entirely upon the grid potential, provided that both the cathode and the plate voltages do not vary. In this respect, the grid in the CRT is similar to that in an ordinary triode; its construction, however, differs considerably. Instead of the wire mesh, or spiral of a triode grid, we simply have a circular plate with a very small hole at its center to allow for the passage of the electron stream. By changing the voltage on the grid, we may therefore vary the number of electrons striking the fluorescent material of the screen and thus increase or decrease the brightness (intensity) of the spot appearing on the screen.

CAUTION.—Do not use a blazing image—it will burn the screen and ruin the tube.

Focus Control

If the grid and anode shields were the only means of forming a beam, the holes would have to be very small to form a narrow beam and so many electrons would be lost that the spot on the screen would be too dim to be of use. Fortunately, larger holes can be used and few electrons lost because the electric field between anodes 1 and 2 acts as a lens which focuses the electrons into a narrow beam. The field between anode 1 and the cathode and grid also has a focusing effect of lesser importance.

How the Electron Beam is Accelerated (Speeded Up) and Focused

Up to this point, we have seen how the electron gun can accomplish the first two of its functions. Focusing and accelerating, the final functions of the electron gun, are assigned to the field between the first and second anodes. This field is the electron lens. By turning the focusing knob in either direction until the smallest diameter

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spot appears on the screen, we will obtain the correct focus. In almost all scopes, the second anode is grounded and focusing is accomplished by changing the voltage on the first anode, which for this reason usually is known as the focusing anode. The second anode is often referred to as the accelerating anode. Remember that the field (electron lens) between the anodes does both the accelerating and focusing and that the anodes themselves can do neither.

Thus far, we have only discussed the effect on focusing, which a change in voltage on the first anode produces. Since the largest voltage rise in the cathode ray tube occurs between the first and second anodes, most of the acceleration takes place in that region, acceleration being directly proportional to voltage. By changing the voltage of the first anode, it would appear that we were changing the final speed of the electrons. However, the over-all voltage rise (from cathode to anode No. 2) remains constant; hence, by changing the first anode's voltage, we merely allocate part of the acceleration either from or to the region between the cathode and the first anode and no variation in the final speed of the electron will occur. In our analysis of intensity control we assumed that only the voltage of the grid was varied. However, as we have seen above, a change in focus will also cause the field between cathode and first anode to vary, which will be evidenced by a change in intensity. Furthermore, a change in the intensity control will have a slight effect on the focusing adjustment. In other words, both focus and intensity depend on each other, and repeated alternate adjustment may be necessary to obtain the ideal trace having a sharp clear spot with sufficient intensity to permit easy observation.

Deflection Plates

A set of four metal deflection plates provides a means for moving the electron beam across the screen so that an image may be formed. Although there are various ways to accomplish this, we will confine our discussion here to the electrostatic deflection method.

Electrostatic CRT

The electrostatic type CRT has both horizontal and vertical deflection plates. The front section of the plates is bent outward to prevent the beam from striking them when extreme deflections are applied. In the number of scopes, one of a set of each of the two sets of deflection plates, together with the second anode, are connected to ground potential. This connection makes possible the operation of the deflection mechanism at or near ground potentials. Provision thus is made for protecting personnel as well as preventing formation of excessive stray fields next to the plates. This latter might cause distortions in the deflection of the beam. In tubes having an aquadag or graphite coating on their inner surface to absorb secondary electrons emitted from the screen, this coating is also connected to the ground.

Let's follow the path of the beam of electrons. First, the electron gun produces the thin beam of electrons. These electrons shoot out the small hole in the end of the gun. Then the beam passes between the vertical deflecting plates. (A voltage applied to these plates moves the beam up or down.) Next, the beam passes between the horizontal deflecting plates. (A voltage applied to these plates moves the beam to the right or left.) Finally, the beam strikes the fluorescent screen where you see it. If the beam is not deflected it will appear as a luminous dot. But with voltages applied to the deflecting plates, the movement of the dot will produce a trace of lines.

Now let's take one set of deflecting plates at a time and see how they control the beam. When an A-C voltage is applied to the vertical plates, you get a vertical line on the screen as shown in figure 3-8, view A.

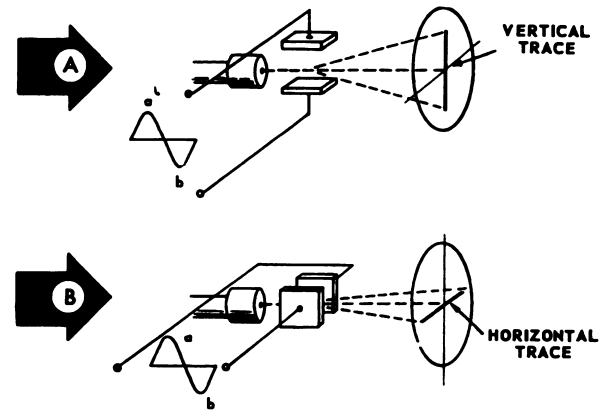

Figure 3-8.—Deflecting the beam to produce horizontal and vertical lines.

If you review the laws of electric charges, you will understand the illustration easily. As you know, an A-C voltage changes polarity each alternation. Thus, during alternation A (fig. 3-8),

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assuming the top plate is positive, the beam will be deflected upward because the positive plate attracts the negative electrons in the beam. Then, during alternation B, the A-C voltage on the vertical plates reverses polarity and the beam is deflected downward. Should the same A-C voltage be applied to the horizontal plates as shown in view B of figure 3-8, you get a horizontal line on the screen. This is called a trace or sweep.

It is easy to realize that if voltages having different wave shapes and frequencies are applied to both sets of plates at the same time, any number of combination of patterns can be obtained. You will undoubtedly witness the various patterns when troubles occur in the indicators you will operate.

Electromagnetic CRT

The electromagnetic CRT is similar to the electrostatic in many ways. This tube has a filament, cathode, grid, and anode, but does not have deflection plates. The production of an electron beam in an electromagnetic cathode ray tube is essentially the same as in the electrostatic tube. The grid structure is similar, and the use of the grid to control the number of electrons in the beam is identical. Figure 3-9 shows the elements of a typical cathode ray tube using electromagnetic focusing and deflection.

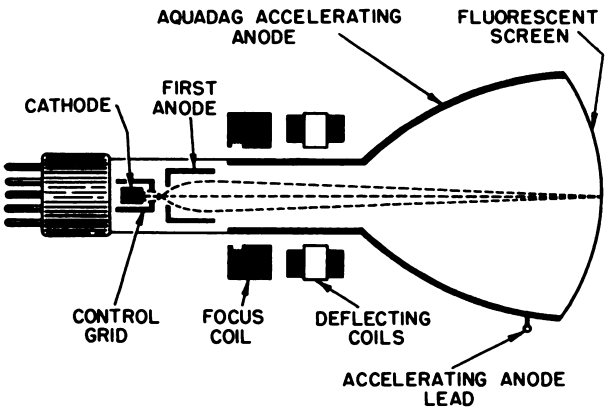

Figure 3-9.–Electromagnetic cathode ray tube.

The focus coil of an electromagnetic tube is wound on an iron core. The core is generally constructed with a small air gap for concentrating the magnetic field. The coil may be moved along the neck of the tube to a limited extent to focus the beam, but the normal method of focusing the tube after the coil is in proper position is to vary the current flowing through the coil. The deflection coils are mounted between the focus coil and the fluorescent screen. They perform the same function as the deflection plates in the electrostatic tube. The coils are mounted on a disk made of nonmagnetic material in such a position that they are directly opposite.

The disk is geared to an electric drive motor. The electric motor and the antenna drive are connected to the same control unit so that, when the antenna rotates, the electromagnets also rotate at the same speed. When a current of electricity flows through the coils of wire, an electromagnetic field is formed. One end of the magnet becomes a north pole, and the other end a south pole. The area in between the poles is the magnetic field.

The beam of electrons is shot into the magnetic field, and is pushed sideways at right angles to the magnetic field. If the current stops flowing in the coil of the electromagnets, the electron beam returns to the center. If another blast of current is sent through the coil, the beam will once more be pushed to the side; but it will return to the center as soon as the current in the coil stops flowing. Each time the transmitter sends out a pulse, an electric current is made to flow through the coil, thus pulsing the beam away from the center. Since electromagnets are constantly rotating and the transmitter is pulsing several times a second, the indicator screen gives the appearance of a bright line radiating outward from the center and rotating about the face of the indicator. A combination of the number of sweeps, the persistency of the screen, and the tendency of the eye to hold the image cause a constantly moving dot to look like a line.

RADAR TRANSMITTING METHODS

There are three types of radar transmitting methods: continuous wave, frequency modulation, and pulse modulation.

CONTINUOUS WAVE METHOD

The continuous wave (CW) method of detecting a target uses doppler effect. The frequency of a radar echo is changed when the object which reflects the signal is moving toward or away from the radar transmitter. This change in frequency is known as doppler effect. A similar effect in audible frequencies is recognized when the sound from the whistle of an approaching train appears

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to the ear to increase in pitch. The opposite effect occurs when the train is moving away from the listener. The radar application of this effect permits a measurement of the difference in frequency between the transmitted and reflected energy and thus determination of both the presence and speed of the moving target. This method works well with fast-moving targets, but poorly with slow or stationary targets. CW systems are therefore limited in present usage.

FREQUENCY MODULATION METHOD

In the frequency modulation method the transmitted energy is varied continuously and periodically over a specified band of frequencies. The instantaneous frequency of the energy being radiated by the antenna consequently differs from the instantaneous frequency received by the antenna from the target. The frequency difference depends on the distance traveled and can be used as a measure of range. Moving targets produce a frequency shift in the returned signal because of doppler effect, however, and this affects the accuracy of range measurement. This method, therefore, works better with stationary or slow-moving targets than with fast-moving ones.

PULSE MODULATION METHOD

In the pulse modulation method the RF (radio frequency) energy is transmitted in short pulses in which the time duration may vary from 1 to 50 microseconds. If the transmitter is turned off before the reflected energy returns from the target, the receiver can distinguish between the transmitted pulse and the reflected pulse. After all reflections have returned, the transmitter can be turned on again and the process repeated. The receiver output is applied to an indicator that measures the time interval between the transmission of the energy and its return as a reflection. Because the energy travels at a constant speed, one-half the time interval becomes a measure of the distance traveled by the pulse to the target, or the range to the target. This method does not depend on the relative frequencies of the emitted and returned signals or on the motion of the target, so difficulties experienced in the CW and FM methods are not present. The pulse modulation method is used almost completely in military applications. It is the method discussed in this book, therefore.

HISTORICAL DEVELOPMENT OF RADAR

In spite of many claims for credit, radar was never actually "discovered" by any one person or group of persons.

In his theory of electromagnetism published in 1873, James Clark Maxwell predicted, by means of pure mathematics, the possibility of radio waves. He speculated that radio waves could be reflected and that they would travel at the same speed as light (186,000 miles per second).

In 1888 Heinrich Hertz performed laboratory experiments which proved that radio waves could be generated and that their characteristics were the same as predicted by Maxwell. Hertz had only primitive apparatus available, and he succeeded in transmitting radio waves only a few feet. However, he definitely proved that high-frequency radio waves could be reflected, refracted, and focused by methods which were approximately similar to those used with light rays. From the wavelength and frequency, he calculated that radio waves traveled at the same speed as light.

In 1895 Marconi began a series of experiments aimed at transmitting radio waves over long distances. With equipment based upon Hertz's apparatus, he succeeded in transmitting signals across the English Channel in 1899. Approximately 2 years later he was transmitting signals from England to Newfoundland.

Marconi announced in 1922 that he had noticed the reflection of radio waves by objects many miles away. He predicted that radio waves could be used to detect objects at great distances.

That same year (1922) two American scientists, Dr. A. Hoyt Taylor and Leo C. Young, working at the U.S. Naval Research Aircraft Laboratory, Washington, D.C., recognized the principle of radar.

Between 1922 and 1930 further tests proved the military value of this principle for detecting objects hidden by smoke, fog, or darkness. Dr. Briet and Dr. Tuve made a large number of experiments to determine the height of ionized layers in the earth's atmosphere. The method used was to direct a brief pulse of radio waves up into the atmosphere and time the interval until a reflection came back. This was the beginning of RAdio Dection And Ranging (RADAR) on a practical scale and led to the application of the principle to detecting aircraft.

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During the 1930's the British, alerted by the Taylor-Young experiments, independently developed radar, which they called the radio locator. By September 1940, their radar was perfected to such a stage that they were able to bring down great numbers of enemy airplanes, thus giving radar the credit of a great importance in winning the Battle of Britain.

The U.S. Navy ordered radar for her ships in 1936. The first vessel to use it was the battleship USS *New York* in 1938.

It was announced in 1943 that radar was the greatest secret of World War II, although it had been in use since 1940-41. During this time scientists and their assistants worked in secrecy at the Radiation Laboratory at Massachusetts Institute of Technology which was to become known as the world's center of knowledge of radar.

During the years following, much development was done by the Naval Research Laboratory, the Army Signal Corps Laboratories, and various commercial laboratories. Research was carried out in other countries—notably in England.

Since World War II, progress has raced ahead so rapidly that in 1946 radar contact was made with the moon. Practically all Navy ships now have radar equipment that would have been unheard of just a few years ago.

DEVELOPMENT OF CIC

Introduction of radar as a principal means of collecting tactical information created need for a centralized agency to coordinate data received from all other sources with that furnished by radar.

First attempts to control radar information involved posting on a display board the data concerning enemy contacts. This data posting was kept current to provide the conning officer, the commanding officer, or the flag officer embarked the necessary tactical information for determining a course of action. The agency handling radar data was called radar plot. Functions of the organization controlling the radar plot crystallized into collection, display, evaluation, and dissemination of combat information. And with increased experience in fighter control and fire support, important control and assist functions were added. Thus was formed the combat information center (CIC for short).

THE COMBAT INFORMATION CENTER

CIC is an agency especially instrumented with such equipment as has been approved by the Chief of Naval Operations for the specific type of ship involved. It is manned by a team of trained personnel under the direction of the CIC officer. CIC is responsible primarily for processing combat information and, in certain tactical situations, may be delegated the authority to originate action based on this information.

FUNCTIONS OF CIC

The five functions performed by CIC in processing all the available information originating from sources inside the ship and from outside involve (1) collection, (2) display, (3) evaluation, (4) dissemination, and (5) control and assist.

The type of information handled includes all data pertaining to the tactical situation which is useful or may become useful in the over-all operation of a ship, a unit, a group, or a force.

Dissemination of evaluated information to command, to control stations, and to those units or commands concerned with the tactical situation is a major responsibility of CIC.

Evaluated information may include the location, identity, and movement of friendly and enemy aircraft, missiles, surface ships and craft, and subsurface units in a given area. When furnishing close amphibious support, additional evaluated information would include locations and movements of friendly and enemy troops and equipment.

The effectiveness of CIC is determined by the skill with which you help perform the five routine functions—the radar operator, sound-powered telephone talker, and plotter. These are all equally important jobs.

COLLECTION

By means of interior and external communication systems, CIC collects tactical data from the following sources:

1. Radar and radar intercept equipment, including airborne equipment.
2. Sonar and sonar intercept equipment.
3. Radio and radio intercept equipment.
4. Visual lookouts and communications.
5. Publications (operation plans, operation orders, etc.).

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DISPLAY

The data collected by CIC are displayed promiently on the following standard displays:

Summary Plot

A comprehensive RELATIVE display of the positions and/or tracks of friendly, enemy, and unidentified forces; geographical reference points; dangers to air and surface navigation; wind direction and speed; the positions of outlying picket forces; and raid designations. The summary plot, the principal display in CIC, is kept in terms of polar coordinates (ranges and bearings) with reference to own ship, and is primarily a picture of the air situation. The specific uses of the summary plot in any tactical situation are governed by the requirements of the situation. In any case, all information plotted on the summary plot should be appropriate to the range scale in use, and the over-all picture.

Geographic Plot

A TRUE display of the positions and/or tracks of friendly, enemy, and unidentified surface, subsurface, and certain air targets; geographical points; and other objects, moving or fixed. The specific uses of the geographic plot vary with each tactical operation; but, used with the surface plot, the geographic plot is an essential display in any surface operation.

Surface Plot

A comprehensive RELATIVE display, kept in terms of polar coordinates, of the positions and/or tracks of friendly, enemy, and unidentified surface and subsurface targets; geographical points, and other objects, moving or fixed. On the surface plot all ships in the formation are displayed relative to own ship. This plot is kept on the maneuvering board, VG, PPI (types of radar repeaters are explained later), or any one of a variety of polar plotting surfaces. Used with the formation diagram, the surface plot is a valuable aid in maintaining a display of all ships in a formation. It is also useful for rapid relative movement solutions in station changing and tracking of unidentified contacts.

Formation Diagram

A display, kept in terms of polar coordinates, of all stations in a formation of ships. On the formation diagram all ships in the formation are displayed relative to the formation axis and center and the screen axis and center. The formation diagram, often maintained on a maneuvering board, is a valuable aid in determining the positions of new stations in formation and screen maneuvers and in displaying the formation on the surface plot relative to own ship in the center.

Strategic Plot

A large area TRUE display on which is plotted information on the position, movement, and strength of own and enemy sea, land, and air forces within a prescribed area of operations. This display is maintained on hydrographic charts of suitable scale with information for it taken from operation plans and orders, intelligence reports, and reconnaissance. As its name suggests it is a graphic display of the strategic situation as known by the plotter.

Conversion Plot

A display used to convert a report made in terms of rectangular grid coordinates to polar coordinates or vice versa. The conversion from grid to polar coordinates is accomplished by superimposing a polar coordinate display over a rectangular grid. The conversion plot is not necessarily a separate plot, but may be combined with any of the basic plots, such as the summary, surface, or geographic plots.

AA Coordination Plot

A RELATIVE display of the actual position of the ships in the formation and used by the officer assigned to coordinate the AA gunfire of the ships in a formation. In addition this plot may be used by the gunnery liaison officer (GLO). Included on this plot are limiting firing bearings, special watch zones, and such other information as may be required by these officers.

Status Board

A convenient and prominent display of tactical data. The size and purpose of status boards vary with different types of ships. The data displayed thereon also will vary. In general, all current tactical information not displayed on standard plots and charts is displayed on status boards. Included are navigational, tactical maneuvering, and meteorological weather information; status of airborne aircraft; radio frequencies and voice

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calls; radar, IFF, and radio guard assignments; conditions of electronic silence; and so forth.

Charts

Display of tactical and strategical information on navigational and grid charts. The area covered by charts varies with the scope of the operation, ranging from wide area charts to those used in radar piloting and naval gunfire support. The information displayed on charts ranges from the track of a movement to an objective area to a record of individual engagements during the movement and in the objective area. In general, charts are used for displaying information which is beyond the range of the standard plots or which is of a more permanent nature.

EVALUATION

Appraisal and determination of the tactical significance of information collected and displayed in CIC is known as evaluation. Evaluation starts with you (as a radar operator) estimating the type (surface or air), size, and altitude of contact. Then you pass ranges and bearings to the plotter who determines the course and speed. Then the evaluator (or exective officer) or CIC watch officer makes recommendations to conn.

DISSEMINATION

Dissemination "passing the word" is perhaps the most important of the five CIC functions. All information that has been collected, displayed, and evaluated must be distributed without delay to those who need it for proper performance of their duties. Command makes all ultimate decisions on the action required. Therefore command must be informed. Other stations must be prepared to act as directed by command, so they must receive complete information on matters relating to their duties.

CONTROL AND ASSIST

Having collected, displayed, evaluated, and disseminated each new bit of information, CIC may be designated by command to perform certain control and assist functions. These functions are dictated by the tactical situation and are determined by the availability of space, equipment, and trained personnel.

ORGANIZATION OF CIC

As a Radarman you are required to have some information regarding the division organization of which you are a part.

Personnel complements and requirements vary with the type of ship. The organization, however, is standard regardless of the size and type of ship, and personnel are employed in the same way, depending on the current mission or tactical situation.

Normally, all Radarmen and strikers are assigned to the CIC division (OI) for duty and administrative purposes. The OI division is a part of the operations department, which may also include a lookout and recognition division (OL). The operations officer is head of the department, and the CIC officer is the OI division officer. The operations officer is also assisted by the communication officer and electronics material officer, and, if the ship is large, by several junior officers.

Personnel complements are controlled by the Chief of Naval Operations and the Chief of Naval Personnel. Requirements for each type of ship are based upon the size of the ship, the functions for which the ship was designed, and the number required to man a minimum number of positions during normal cruising on a continuous watch standing basis. In general, a sufficient number of officers and men are assigned regularly to CIC duties to permit at least a three-section watch during normal, customary operations of the ship type. In this respect the requirements of an aircraft carrier, for example, would be much greater than those of a supply ship or minesweeper. To provide extra "off-duty" time for your formal instruction and training during operating periods, a four—section watch may be set up. Your particular organization may vary accordingly. Usually there is a leading Radarman, senior in rate or time, then a section leader for each section. Some ships call this man a watch captain or watch PO. He is usually an RD3 or RD2, charged with the responsibility of ensuring that CIC operates smoothly and efficiently at all times when he has the watch.

The difference between a Radarman Third and Second is that a Second is more proficient in carrying out a radar operator's duties. He has the advantage of greater experience and more radar training. Because of the similarity between the two rates, this manual is written to cover the qualifications of both.

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RESPONSIBILITIES OF CIC PERSONNEL

The burden of defense rests squarely on early warning from air and surface radars. It is vital that you understand this problem and, more so, understand that as a Radarman this responsibility is directly upon your shoulders. All of our newly acquired missiles, rockets, etc., are of no practical value unless the Radarman detects the enemy first with his radar.

One particular type of plane heading straight at a radar antenna displays only 40 square feet of reflecting surface. You can see the problem of detection if you are "on scope." It takes a keen eye and a lot of know-how to first see the target, then evaluate it. Submarine periscopes are even harder to detect.

As you study this text, you are preparing yourself for Radarman Third or Second—a petty officer and a leader of men. Your responsibilities as a leader are twofold: the accomplishment of your mission and your duty to your men.

No individual is prepared to undertake his assigned duties until he understands the mission and the part he is to play in accomplishing it.

This text will help you learn the techniques of operating a radar. When you stand watches in CIC, you will be rotated from one position to another, to relieve eyestrain from looking at the scope too long. Step by step, as you successfully complete one job after another, you will become surer of your ability to tackle a new job and complete it successfully. Do each job well as you come to it. If you don't know how to do it, find out from someone who does know.

The responsibility of a pettty officer doesn't stop with putting the "crow" on. You must learn what has to be done, how to do it, then do it to the best of your ability. If you do this, your confidence will blossom and flourish and so will the confidence others have in you. CIC has no place for doubt; ships and aircraft move at such great speed that there is no room for mistakes. The evaluator, CIC officer, CIC watch officer, and even the Captain, will ask advice from you occasionally. They must have confidence in your recommendations.

QUIZ

1. If a person shouts in the direction of a cliff and there is a 2-second interval before he hears the echo, how far is the cliff?
2. What three measurements may be made with the apparatus shown in figure 3-2?
3. What is the speed of radio waves in meters per second?
4. What are the three principal uses of the electron gun in a cathode ray tube?
5. Why is air generally evacuated from electron tubes?
6. What is the purpose of the anodes in the cathode ray tube?
7. What control on the front panel of the indicator governs the brightness of the sweep?
8. How can you vary the number of electrons striking the fluorescent material of the screen and thus increase or decrease the brightness of the sweep?
9. What does the electrostatic cathode ray tube use to control the beam and produce a trace of lines?
10. What radar method uses doppler effect?
11. Why are the problems experienced with the CW and FM radar methods not present in pulse radar?
12. What are the routine functions of CIC?
13. To what division are Radarmen assigned aboard ship?

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CHAPTER 4

USES OF RADAR

WHY THE NAVY NEEDS RADAR

The Navy needs radar because of the advance information or early warning it can give. Radar can show the presence of surface contacts (such as ships, periscopes, boats, icebergs, rocks, shoals, or land masses) and air contacts such as aircraft or storm clouds.

The radar operator can tell the approximate size and the relative movement of the contact. This information when reported, plotted, and evaluated can tell speed and direction of movement of the contact. In other words, radar can help predict events before they happen and can give information that will be valuable to command. This includes intercepting an enemy contact--avoiding collisions or grounding, allowing safe navigation, and providing information for: shore bombardment, air interception, rescue search operations, and tactical maneuvering with friendly ships and aircraft.

Radar does away with the handicaps of darkness and bad weather. Radar provides an all-seeing eye which allows YOU to SEE night or day, rain or shine.

BASIC RADAR TYPES

The fundamental principles of all radar sets are alike. However, radar lends itself to many different uses, requiring a different application or frequency, pulse repetition rate, beam width, pulse width, antenna rotation rate, etc. As a whole, naval radar equipments are used for three general types of jobs: search, fire control, and special. The types of radars you will operate aboard ship are (1) surface-search, (2) air-search, (3) low-angle search and height-finding, and (4) identification (IFF).

Every radar set has a host of controls and switches. Unfortunately for the RD3, the controls on different sets are placed in different positions on the operating panels. You must learn what the controls are, where they are located, and what they do. Radars also must be operated under changing conditions. You must analyze a given situation and be able to adjust the controls to obtain the maximum information from the set, regardless of operating conditions.

You must know what range scale to use for a given situation and when the scale should be shifted. You must know when to set the gain control at high, low, or medium, how fast the antenna should rotate; and whether the antenna should be stopped to check a target, and for how long. You must know how to read the range scale, whether to use the range step and associated dials when provided, and when to use estimated ranges.

If the radar set is equipped with two or more types of cathode ray indicators, you must know which to use, and under what conditions one is preferable to another.

SEARCH RADARS

The search or early warning radars that you will be operating are of two types — surface and air. Search radars do not require great accuracy in determining bearing and ranges but do require the ability to detect and track targets at relatively long ranges. This does not mean that you do not have to be accurate when reporting bearings and ranges to the plotter, especially when tracking a surface target. On the contrary, since the search radar is designed so that it sacrifices accuracy for better long-range detection, it takes more concentration and skill on the operator's part in getting accurate bearings and ranges so the plotter can obtain a good solution of course and speed of the contact.

Search radar sets always have an antenna that rotates and scans through 360°. The primary scope indicator is a PPI. There also may be a separate range scope but it is not required. Some of the modern equipments do not have an indicator unit, as such, but rely on remote indicators (RPPI's) (to be discussed later) for visual indication, which reduces the

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over-all equipment space requirements. Some of the other advantages of the RPPI are that it —

1. Reproduces any desired radar information at several selected locations remote from the radar room.
2. Permits a given radar to be used in two or more applications at the same time, as station keeping and surface searching.
3. Provides direct assistance in piloting and station keeping by showing the PPI indication of the surface-search radar.
4. Provides, with the use of attachments that produce expanded sweeps, a more desirable presentation of radar information.

Surface-Search Radars

You employ this type of radar to get range and bearings of targets on the surface. These radars provide information with greater precision than air-search radars. You can also use surface-search radar to detect low-flying aircraft and track helicopters. Surface-search radars generally are used to control helicopters in antisubmarine operations.

Surface-search radars are normally long-range equipments. They are restricted, however, in actual detection range by the curvature of the earth's surface. For this reason the surface-search radar antennas ordinarily are located as high on the mast of a ship as possible. In some instances, because of atmospheric conditions, the radio waves will follow the curvature of the earth and detect targets at a range greater than the radar horizon, but these atmospheric conditions are not dependable.

The term "surface-search" is misleading since it is only one of many functions performed by this type of radar. Here are some of your duties as surface-search radar operator:

1. Detect the presence of enemy surface craft that are beyond visible range at night or during conditions of poor visibility.
2. Coach fire control radars to enable them to get on target quickly.
3. Provide security against attack at night, during conditions of poor visibility, or from behind a smokescreen.
4. Aid in scouting to detect the enemy, keeping track of your force so you can rejoin quickly.
5. Obtain range and bearing on prominent landmarks and buoys as an aid to piloting, especially at night and in conditions of poor visibility.
6. Help in station keeping, especially at night and in poor visibility.
7. Detect snorkling submarines and low-flying aircraft.
8. Use surface-search radar to back up fire control radar in conjunction with precision PPI.
9. Determine spots on shell splashes in both range and bearing, especially if your ship is not equipped with fire control radar.

Remember that surface-search is the primary function of this radar, and the one for which it is best designed. When you are the surface-search radar operator, detecting targets and hazards is equally as important as using the radar for keeping station or radar piloting.

Air-Search Radars.

As the name implies, air-search radars are for the purpose of scanning the skies for planes or other aerial targets. Because of the greater power output possible at the lower frequencies, and the characteristics of their antennas, coupled with the normally higher targets (airplanes), it is possible to obtain greater ranges than with surface-search equipments.

The speed of present-day aircraft requires early detection at great distances if a prompt and swift defense is to be formed. Most air-search radars you will be operating have ranges up to 200 miles; as aircraft speed increases, newer radar will no doubt be designed and operate at greater ranges.

With air-search radar you measure range and bearing to a fair degree of accuracy since they sacrifice range and bearing resolution by having a longer pulse width and wider beam width in order to gain increased range. You also utilize air-search radars to detect surface targets, although this is the primary function of surface-search radars. Air-search radars often are used for long-range navigation.

The PPI-scope is used extensively with air-search radars because the PPI provides an instantaneous display. Modern aircraft move

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so rapidly that you will find it necessary to plot the targets on the scope face with a grease pencil in order to retain some of the information that appears temporarily on the scope. The reflection plotter, a unit used with repeaters, is the device that enables you to do this (discussed in chapter 7).

When you are the air-search operator, here are some of the things that will be done by you or someone else at the same time, on another repeater, using the air-search radar.

1. Detect approaching aircraft before they can be sighted visually, so that —
   a. The direction from which attack may develop can be indicated.
   b. Fighters may be launched in time if an air attack is imminent and a carrier is in company.
   c. AA defenses may be brought to the proper degree of readiness in sufficient time.
2. Keep track of movements of enemy aircraft, and control of own fighter planes to a position suitable for interception.
3. Provide security against night attack, attacks during conditions of poor visibility, or from behind a smokescreen.
4. Aid in scouting.
5. Aid in navigation. (At times air-search radars can range on land up to 150 to 250 miles.)
6. Detect certain weather phenomena.

FIRE CONTROL RADARS

Because Fire Controlmen operate fire control radars, you are not required to know this type of gear. However, some of the information concerning them may be of help in understanding more about your ship and CIC.

Fire control radars are designed as part of the over-all gun-control systems. Unlike air- and surface-search radars, they are capable of a high degree of accuracy. Since they have extremely high frequencies, high pulse repetition rate, short pulse width, and narrow beam width, they can determine bearing range and altitude with sufficient accuracy for controlling gunfire. These radars may also be used in a search function if the situation permits, although the detection range is rather limited. On guided missile ships, the missile guidance radars are part of the fire control system.

Generally, fire control radars are used only after targets have been located by the search radars or when designated certain search responsibilities. Fire control radar can be used very effectively for CIC assist piloting.

Since fire control radar is not designed as search-radar and has other limitations in its operation, the assistance rendered by CIC in gunfire control is particularly important. CIC performs the following functions:

1. Detects the target.
2. Determines the identity of the target and keeps gunnery liaison personnel and gunnery control stations informed of the evaluated situation, including an initial solution of course and speed, and altitude if target is airborne.
3. Furnishes the information to gunnery liaison personnel who assist the fire control radars to acquire the target.
4. Scans the firing areas to ensure protection of friendly units.

The characteristics of the search and fire control radars in use must be thoroughly understood by gunnery and CIC personnel to render assistance intelligently. Personnel at gunnery control and gun director stations should be acquainted with the type and extent of information from CIC, the methods by which this information is derived, and the channels by which it is disseminated. Correspondingly, you should be familiar with the gun batteries and the target designation system.

It is of interest to you to know the sequence of events in a fire control problem. They are indication, target designation, and target acquisition.

Target Indication

Target indication is the information report to the task organization commander of targets within the air defense area. It includes all information available for proper designation, such as the presence, identity, location, size, number, course, speed, and estimate of intent, plus any additional evaluated factors necessary for proper designation.

Target Designation

Target designation is the selection by command of the specific targets to be taken under fire, and the transmission of data to help in acquisition of targets by the selected ships and gun or missile batteries.

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Target Acquisition

Target acquisition is the process of positioning the tracking apparatus of a control system so that a designated target is located by a particular fire control system or fixed in the optics of a gun direction system.

Some applications of fire control radar are that it —

1. Supplies accurate ranges, bearings, and position angles to the computer so that a solution to the fire control problem may be obtained more quickly than by optical means.
2. Indicates spots in both range and deflection by ranging on shell splashes. At short ranges it is possible to follow some projectiles on the radar throughout their entire flight.
3. Is used for calibrating antiaircraft projectile fuzes by comparing range of burst with fuze settings.
4. Supplies data for directing starshell or searchlight illumination.
5. Obtains meteorological data by observing movements of balloons equipped with radar reflectors.
6. Detects low-flying aircraft.

SPECIAL RADARS

In the past, radar types were grouped into the following categories: surface-search, air-search, low-angle search and height-finding, fire control, IFF, radar beacons, airborne intercept equipment, and bombing apparatus. In this text, radars used for specific purposes will be referred to as SPECIAL RADARS.

Height-Finding

Height-finding radars are used with air-search radars. After the aircraft is detected on the air-search radar, you train the height-finding radar antenna to the bearing and look at the proper range on the range-height indicator scope (RHI) for altitude. The RHI displays radar data in terms of horizontal range and altitude rather than in range and bearing, as is the case with a PPI. RHI are used only with height-finding radars. When the tactical situation permits, and if you are the height-finding operator, you may be directed to search for aircraft, particularly for low-flying aircraft; or you may be directed to use the height-finding radar as a high-power surface-search radar. Height-finding radars also are used to obtain meteorological data by tracking weather balloons.

Some of the duties of the height-finding radar operator are to —

1. Obtain accurate range, bearing, and altitude data on enemy planes to assist in control of own fighter planes to a position suitable for interception.
2. Keep track of own fighter planes while they are within range of the radar.
3. Search for low-flying aircraft.
4. Serve as surface-search radar when no air attack is imminent.
5. Detect certain weather conditions.
6. Assist in radar navigation by ranging on mountain tops or distant land.

Recognition —IFF

Because radar equipment cannot distinguish friendly from enemy signals, a special piece of gear has been developed to accomplish this task. Known as IFF, it is covered in *Radarman 3 & 2, Vol. 2.* Another special equipment is the radar beacon. (It also is discussed fully in volume 2.)

Identification is initially conducted with search. The search radar operator challenges the target by operating the IFF interrogator. This equipment sends out pulses to trigger a unit called a transponder that is carried by the friendly plane or ship. If the target is friendly and sending proper recognition signals from its transponder unit, a coded pattern appears on the originator's indicator screen at the search-radar. If the target is unfriendly and is not returning proper signals from a transponder unit, no pattern appears on the screen. The IFF transmitter is synchronized with the associated radar equipment so that a "challenge" pulse from the transmitter is fed to the identification antenna and is sent out at the time that a pulse is transmitted by the radar equipment. This serves to place the identification reply signal at the same spot as the radar echo signal.

Recognition equipment is used with radar to —

1. Identify on the radar screen the echoes from friendly aircraft and ships by returning a coded response.
2. Indicate friendly aircraft at distances in excess of the maximum range from which radar echoes can be obtained.

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3. Identify to the aircraft controller which echoes of a group are the fighters over which he has control.
4. Act as a beacon, using a code selected for the purpose.
5. Indicate distress by producing on the radar screen a much wider signal.
6. Allow radar to follow friendly planes through null (no signal) areas in antenna pattern, or through severe clutter like that produced by weather, if the echo from weather is not too strong.

Ground and Carrier-Controlled Approach

This type of radar (called GCA or CCA) is operated by the Air Controlmen on a carrier or airfield. CCA radar is used to control aircraft on carriers, and provides glide path information to the landing planes.

Range Rate

A speed-measuring radar used for carrier controlled approach, this radar is also operated by the Air Controlmen, who are part of the OI division on some carriers. It is used to measure the speed of the landing plane.

INFORMATION OBTAINED FROM RADAR

It is difficult to overemphasize the importance of radar, whether it is used to detect aircraft and protect ships and shore installations from surprise attacks, or to direct and fire guns, support land operations (e.g., shore bombardment), or as a nagivational aid. In all these applications, the radar set must be in good working condition. Radar will be in good condition and do what is expected of it only after you master control of it and properly maintain the equipment and make necessary adjustments for best performance.

When operating a radar, you must bear in mind the great responsibility placed upon you. You are the first aboard to know of the enemy's presence, strength, and precise location. Before the captain can begin to maneuver the ship, and before the gunnery officer can give the command to fire, they must receive your radar information. Of course, if the radar is operated carelessly, it cannot be expected to give results. Radar is capable of performing its task well, but only if there is an efficient, alert operator at the controls. Yours is indeed a big responsiblity, and the safety of your ship and shipmates depends on how well you understand your radar, your job as radar operator, and how well you do your job.

The information you receive from the radar is of no use if you fail to relay the information to the proper place. To be used effectively, information must be received by those with authority to act on it. As a radar operator your duty is to see that those in command, via your CIC watch officer (or, in his absence, the OOD) get the information they need. They are depending on you. Remember, what you tell them or fail to tell them may determine the fate of your ship. Presence, range, bearing, nature, number, size, and altitude make up the data that can be obtained from radar. From these seven, you will see that a lot can be done and much can be learned.

Pips that appear on a radarscope indicate only the presence of targets within the detection field of the radar. Ability to interpret the radarscope picture is an extremely important function of the radar operator.

The position of the echoes on the scope indicates range and bearing which can be obtained without much trouble by any operator. However, to determine the composition of a target, what type, how many, friend or foe, etc., requires a high degree of skill, imagination, and experience. Hints on how to interpret pips are covered in chapter 11.

One thing to remember when you are CIC watch captain, or section leader, is that, in spite of the impressive amount of electronic detection equipment available to modern fleets, the importance of the visual lookout is as great as ever. Because of the nature of the radar antenna patterns, it is possible for an aircraft to come in undetected under or above the antenna pattern. Some times detection can be made only by visual means.

You should alert the lookouts to search in likely sectors for the visual sighting of a target which has been detected by electronic means. Coach them to be especially vigilant for the detection of low-flying aircraft and for small surface targets such as submarine periscopes or snorkels which are difficult to detect by radar.

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TYPES OF PRESENTATION

The "trick" to operating radar, regardless of its design and purpose, is a thorough understanding of the various scope presentations displayed on the screen of the cathode ray tube. The Navy uses many different types of indicators (scopes). If you understand the basic ones, the others will be easy. Thus, we'll show you the more common scope presentations: the A- , R- , PPI- , B- , and RHI-scopes. The A- and B-scopes are used on many ships for surface-search work, and the PPI is highly effective for air operations. The RHI is used with height-finding radars.

A-SCAN PRESENTATION

The A-scan is one of the more common types of presentations used with search radar. It uses an electrostatic cathode ray tube, with short persistence. Many times it is referred to as the RANGE SCOPE or just A-scope. Because of its sensitivity, the A-scan has a great advantage over other scopes when employed for long-range detection. However, its primary purpose is to give the range of the target from your ship. Some scopes provide a range step in the sweep, and control its position electrically to facilitate range measurement. The step appears because a voltage is applied to a vertical deflection plate, which causes the remainder of the sweep to be shoved down. (See fig. 4-1.)

Dials or scales for reading the range of the step directly and accurately are provided. When you move the step under the pip of the target, the range of the target appears on these dials. This greatly simplifies the task of accurately determining range.

Before leaving the A-scope, let us briefly review the facts known about it. First of all, when an object is reflecting the transmitted energy, the spot jumps up, tracing a triangular-shaped pip. The presence of the target, then, is shown vertically.

At the instant the transmitter sends a pulse of energy into the atmosphere, the A-scope starts to trace a horizontal line across the tube face. When the reflected energy is received from an object, it is amplified in the receiver and superimposed on the horizontal sweep. It will appear as a sharp rise in the normally straight appearance of the line. The distance a certain object is from the radar antenna is directly proportional to the distance the rise in the sweep (pip) is to the right of the beginning of the sweep line.

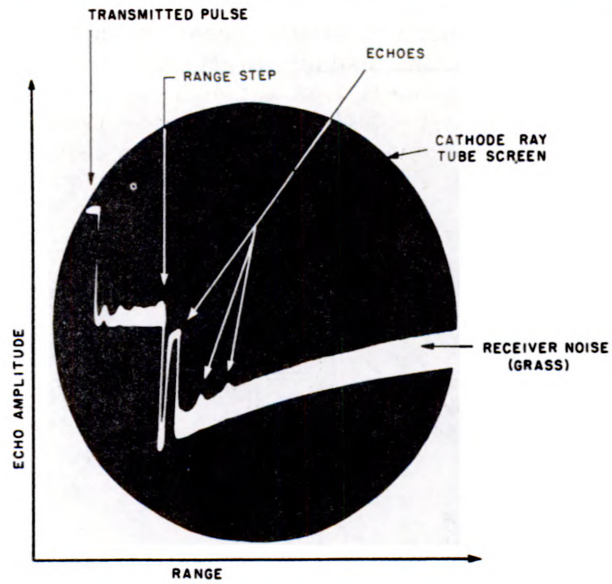

Figure 4-1.—A-scope presentation with range step.

When you plot a given quantity on a graph with respect to time, the first thing you do is label one coordinate of the graph paper with units of time. The other coordinate is indicated in volts, watts, distance, speed, signal strength, or whatever quantity you wish to plot against time. The A-scope is arranged to do this for you automatically—it acts like an automatic graph plotter which plots voltage strength against time. The first step in setting up an A-scope for radar work is to establish a linear time base. From your study of chapter 3 you know this is done by applying a voltage to one set of deflection plates, which increases to its maximum value at a constant rate and then falls instantly to its minimum values. This cycle must be repeated continuously. Figure 4-2 displays such a voltage applied to the horizontal deflection plates; the voltage is called a saw-tooth sweep voltage.

Following the action in figure 4-2, at point a the saw-tooth voltage is at its maximum negative value and the beam is at point a on the screen. As the saw-tooth wave gradually approaches the zero voltage line, the beam is swept to the center of the screen at point b. As the voltage passes through its zero value its polarity reverses and, in turn, the polarities in the plates also reverse. Thus, as the voltage increases further, toward point c, the beam is deflected to the other side of center. Finally, when the voltage reaches maximum positive, the

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beam is at point c on the screen. At this time the voltage snaps instantly to maximum negative at point d. And as it does, the beam is deflected back instantly to point a. This saw-tooth voltage is continuous and sweeps the beam across the screen, over and over, to give the linear time base.

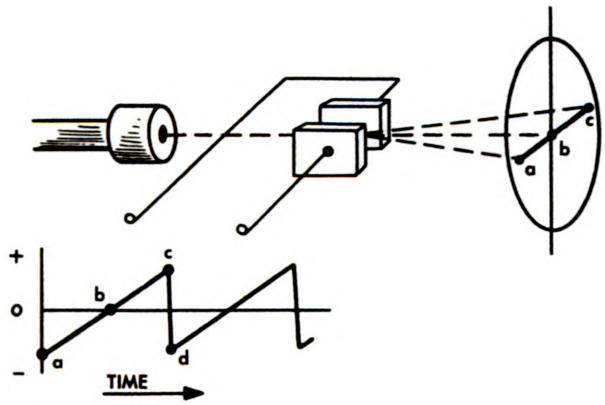

Figure 4-2.—The saw-tooth sweep voltage establishes the linear time base for the A-scope.

Next, examine the action of the cathode ray tube when a signal is applied to the vertical plates and the sweep voltage is impressed on the horizontal plates. Since it takes a certain amount of time for a radar pulse to make a round trip to the target and back, it would be reasonable to expect a voltage pattern like that for the vertical input in figure 4-3 (labeled radar signal). The pulse at the very beginning of the sweep should be noted. This is a signal caused by the transmitted pulse. Unfortunately the transmit-receive switch (duplexer) is not perfect and allows some of the transmitted pulse power to reach the receiver input circuit, thereby limiting the radar set's minimum range. Though only a tiny fraction of the transmitted power, this power is large relative to echo pulse power and causes a large deflection on the indicator screen. This deflection is called a pip.

Now follow the action in figure 4-3. The sweep voltage sweeps the beam from left to right on the scope in a fashion described in figure 4-2. The timer triggers the transmitter and sweep generator so that the pulse starts out the same instant the sweep starts to the right on the screen—this occurs at time t_1 in figure 4-3. The transmitter pulse produces the first pip on the screen, and as the transmitted pulse is making its trip to the target and back, the sweep voltage increases, sweeping the beam to the right. The returning echo is routed to the indicator input and is recorded on the radar screen as a second, weaker, pip—time t_3. Finally, as time t_4 comes around, the sweep voltage falls instantly to zero, and the beam is carried quickly to the left side of the screen in preparation for another sweep. The timer triggers again and the cycle recurs. The persistency of the screen and the pulse repetition rate of the cycle just described are so fast you see only a fixed pattern.

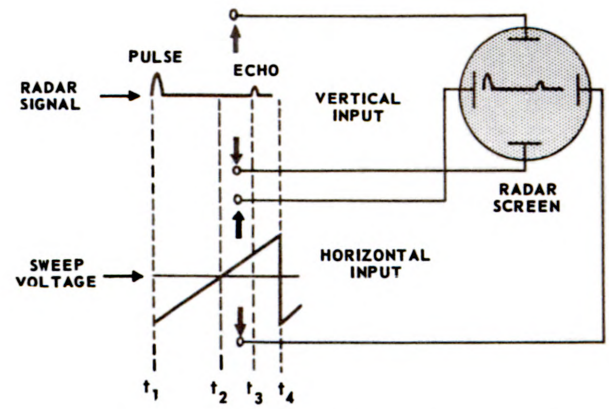

Figure 4-3.—Applying a radar signal to the CRT.

CONTINUOUS AND DISCONTINUOUS SWEEPS

As already explained, the electron beam travels across the A-scope screen in a definite manner in a definite time. Since there is one sweep for every pulse sent out by the transmitter, the time between pulses puts a limit on the time length of the sweep. Sweeps that use up all of this time differ slightly from those that do not, and there are different names for them. They are continuous and discontinuous sweeps.

A CONTINUOUS SWEEP is a sweep in which the dot needs the complete time between pulses to get across the scope. It travels continuously, because it jumps back and starts over immediately after it completes one trip. A DISCONTINUOUS SWEEP is one in which the dot rests awhile after completing its crosswise trip considerably ahead of the time it is to start across again. It shows no echoes during the rest period, because it does not sweep across continuously.

Suppose that a radar set's PRR is 833 times a second. This means that the time between starts of sweeps is 1/833 second, or about 1200 microseconds. If only those targets within

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about 10 miles are the object of radar search, only those echoes coming back within about 10 x 12, or 120 microseconds, need be considered. Since the dot can be set to travel at any chosen speed, it can be made to go across the screen in 120 microseconds. When it reaches the end, it has to wait 1080 microseconds before it can start again. This would be a discontinuous sweep because of the rest period, during which the scope is blanked out (turned off).

If looking for targets as distant as 25 miles, the dot would have to be slowed down until it took 25 x 12, or 300 microseconds, to cross the screen. Its rest period now will be 900 microseconds (with 833 pulses per second). This would be called a nominal range of 25 miles, because that is the biggest range that can be read directly on the scope with this sweep speed.

If the dot were slowed until it took the full 1200 microseconds to go across, the nominal range would be 100 miles. Furthermore, there would be no appreciable rest period. Up to this point, slowing the dot has increased the nominal range. It is not possible to continue to increase the nominal range by slowing the dot still more since only 1200 microseconds are allowed between starts of sweeps. Hence, any further reduction in speed with this pulse repetition frequency will shorten the length of the trace. Further slowing the dot cannot increase the pulse interval—the maximum time of travel. It will shorten the distance the dot travels, and that usually is not desirable.

As long as there is discontinuous sweep, the nominal range can be changed by changing the speed of the sweep. But the only way the nominal range of a continuous sweep can be changed is by changing the PRR. The nominal range is determined by the time the dot takes to cross the screen, and that, for a continuous sweep, is the same as the time between starts of pulses. Increasing the number of pulses decreases the time between them, and so reduces the nominal range.

There are ADVANTAGES associated with the continuous and the discontinuous sweep. As long as a discontinuous sweep is used, you can change scales simply by turning a knob. Since changing the sweep speed is the only thing needed after the nominal range of a discontinuous sweep, a rather simple control can be used to make a quick, easy change. Most remote repeaters are designed this way. The pulsing frequency, on the other hand, cannot be changed much in some cases, so sets with continuous sweeps usually have only one scale.

The sweep speed of a continuous sweep can be changed on some radars so that the sweep starts slowly, then speeds up, and finally slows down again without altering the time of the start and ending of each sweep. The total range indicated by the sweep is unchanged since the total time of the sweep remains the same. However, both ends of the sweep register a great proportion of the total range, for they represent a greater part of the total time because of the reduced speed of the spot. The center portion that has been speeded up now represents less of the total range since its time is reduced, but it represents an increased part of the physical length of the sweep. This results in expanding the picture of any objects appearing in this center section of the sweep because it now covers a greater part of the sweep length. Thus you are better able to obtain composition and evaluate targets on the A-scope more easily and have greater range accuracy.

R-SCOPE

The R-scope, a modification of the A-scope, is of great value in determining the composition of targets, and is found on some sets. It is a magnified (expanded) portion of the A-scope, with a control which enables the operator to choose the part to be magnified.

To magnify the pip on the R-scope, the spot is made to move across the scope in a short time. It may cover the 5 inches (approximately) of the time base in just 25 or 30 microseconds. This, of course, will make the pip appear very wide. For instance, a pip 5 microseconds wide might cover a whole inch on the time base. Two targets separated by only half a mile will appear almost an inch apart. Consequently, the operator is not likely to read the indication as being a pip from a single target.

By increasing the width of the pip in this way the operator can more easily recognize some of its characteristics. He can count the separate peaks running up or down the sides of the pip, and separate targets close together which might otherwise be mistaken for a single target. The job of estimating size, number, etc., is simplified by the use of the R-scope. (See fig. 4-4.)

PPI-SCOPE

The PPI-scope is an electromagnetic type of cathode ray tube that gives a top view of the

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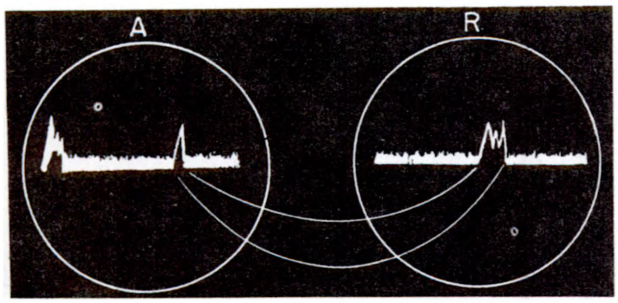

Figure 4-4.—A- and R-scope presentations compared.

vicinity, with own position in the center. Draftsmen call a top view a plan view. Since the scope indicates a top (or plan) view of the position of everything around own ship, it is called a PLAN POSITION INDICATOR or, as abbreviated, a PPI-scope.

The pictures of the surroundings appear by this simple process: The sweep begins in the center and goes outward (at its constant speed) toward the edge in the direction the antenna is pointing, and a bright spot appears at a distance proportional to the range of the target. This method is similar to placing a mark in the correct direction and at the correct range on a polar chart. This is all that is needed to draw a true map of everything in the vicinity. This scope shows everything that can reflect the radar energy and shows it in the proper place on the PPI map. Islands, as well as own and enemy ships and planes, and anything else that happens to reflect the energy, will appear in their actual positions. This PPI-scope is extremely helpful in task force operations, in convoy duty, in working navigation problems, in air operations—in fact in virtually all tactical situations.

Remember that the sweep moves outward in a direction representing the antenna bearing. Since the antenna can pick up an echo from a target, only while it is pointing at that target, and since the rotating antenna points in any target's direction but for a short time, the bright spot (pip) will appear for only a moment. As the radar beam swings away from a target, no echo is received from it, and consequently the beam no longer makes a bright spot. (Remember that the beam can intensify contacts only on one bearing at a time.) This means that in order to continue to see that particular target, the screen must continue to glow after the sweep leaves it. In making the cathode ray tube, the screen is painted with a chemical coating that glows longer than the A-scope screen coatings, and a tube with a longer persistence screen results. A screen is termed persistent because it persists in glowing after the sweep has left it and has moved on to another spot. Tubes which employ the intensity method are used in the PPI- and the B-scopes. Figure 4-5 shows the PPI presentation.

B-SCOPE

The B-scope is mechanically very similar to the A-scope. On the B-scope, however, range is indicated vertically rather than horizontally. Also, the B-scope indicates bearing, but the A-scope does not. Chief advantage of this type of presentation is that its range indication is as nearly accurate as possible. The B-scope is used with fire control radars and the VF type of repeater. (The VF is now obsolete, and is being replaced with more modern repeaters.)

Figure 4-6 shows the PPI- and B-scopes used with the model VF repeater. Precise range measurements are made on the B-scope. The B-scope displays on an expanded scale the echoes selected from a small area on the PPI. The expansion afforded on the B-scope makes it possible to measure range to accuracy of plus or minus 20 yards, and provides improved resolution within the area that the B-scope can display.

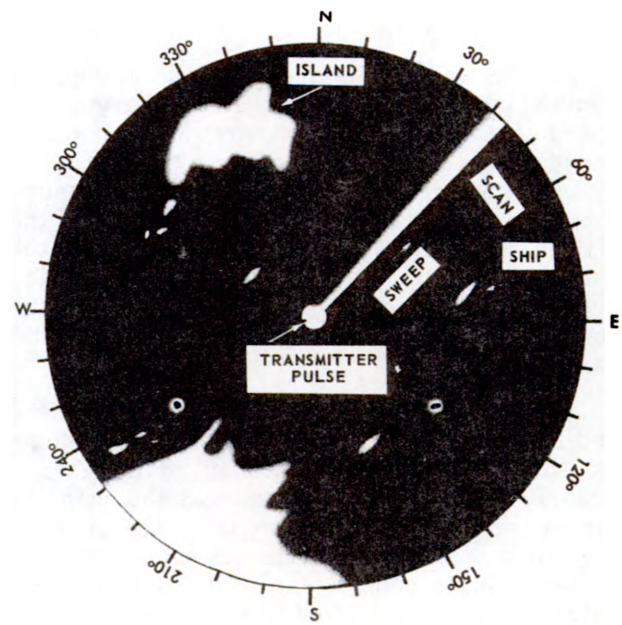

Figure 4-5.—PPI presentation.

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PPI - SCREEN SHOWING TARGETS, RANGE MARKS, INTENSIFIED RIBBON MARKER WITH SEGMENT SELECTED FOR ENLARGEMENT SHOWING BRIGHTLY AT 3 O'CLOCK.

A

B - SCOPE SHOWING ENLARGED PRESENTATION OF TARGETS SEEN WITHIN THE BRIGHTENED SEGMENT IN A. THE GRID IS FORMED BY RANGE AND BEARING LINES.

B

Figure 4-6.—Model VF PPI- and B-scopes.

The B-scope sweep is approximately 4000 yards long, and arranged to show targets 2000 yards on each side of a selected range. The range unit is designed so that only targets within 25 miles can be displayed on the B-scope. The total angular width of the B-scope can be varied from 20° to 50°, equally distributed to either side of the PPI cursor.

The B-scope resembles both the A-scope and the PPI-scope, but has some characteristics of its own. If an A-scope is turned on its side, the range will be indicated upward, or vertically, and the pip horizontally. With the receiver disconnected from the horizontal deflection plates, it will not be possible to get a pip sideways. By connecting the receiver to the grid instead, a bright spot will result which will indicate a target just as a pip does. Seeing a bright spot is indication of the presence of an object, and the spot's position tells the range of the object causing it.

The horizontal deflection plates have been disconnected, and are not in use. Range is determined vertically and presence by intensity, but the one item of major information lacking is the bearing. The horizontal plates, then, can be used to determine the bearing of the object in the following manner.

The area on the PPI which is to be shown expanded on the B-scope is selected by adjustment of the bearing cursor and a ribbon range marker on the PPI presentation. The operator sets the cursor over the desired target, and an area 15° on either side of the cursor is automatically displayed on the B-scope each time the PPI trace passes through this sector. The pie-shaped segment in the left half of figure 4-6, at approximately 085° true, indicates the position of the cursor. The cursor is a thin metal strip and wrinkled at one end to indicate that it is not the end to be used. The center vertical line on the B-scope in figure 4-6 (right half) corresponds to this bearing. Since the bearing of the cursor is always represented on the B-scope by the center dot, it is apparent that only bearings relative to the cursor can be read directly from the screen of the B-scope. Thus, the actual segment of the PPI selected for enlargement is shown by the intensified area on the PPI screen.

Like an A-scope, which does not stay right side up, the B-scope shows range vertically.

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The electron beam brightens the screen when an echo returns, and thus shows the presence by intensity. Finally, the horizontal plates are connected so that it shows the bearing horizontally. It gives the same information as the PPI-scope, but in a different manner.

The B-scope pattern is traced once every revolution, during the time that the PPI sweep is traversing the intensified segment on the PPI. As a result, the B-scope echoes are retraced intermittently only, causing a fast-moving target to seem to move in a series of jumps. Because the B-scope echoes are intermittent, it is difficult to align the echo with the center range line. While the PPI sweep is continuing beyond the intensified segment, the range and bearing knobs can be moved to place the spot directly under the desired echo. Turning these knobs corrects the position of the selected segment so that the echo will be nearly centered on the B-scope when the pattern is retraced.

The range is read from the range counters, and the bearing is read from the bearing circle under the cursor.

The main advantage of a B-scope in a precision repeater is that it—

1. Permits close observation of a small sector while the radar proper surveys the whole 360°.
2. Permits accurate determination of data.
3. Expands a small sector to cover a large area so that it is possible to spot shell splashes in both range and deflection with reasonable accuracy.
4. Enables a ship to keep on station within very small limits.

RHI-SCOPE

The RHI-scope is used to indicate the altitude of a radar contact. The vertical sweep of the height-finding antenna is represented on the face of the scope. Range is shown horizontally. The altitude of a contact is then represented by the distance between the contact's pip and the horizontal range trace. A horizontal cursor is provided to facilitate measurement of this distance.

OTHER TYPES OF SCOPES

There are many types of indicators used with radars having scopes designed for special purposes. Usually these indicators are either modifications or combinations of the kinds you already understand. A majority of the scopes you will use are the types discussed in this chapter.

RANGE DETERMINATION

In the preceding chapter you learned that radar waves travel at the same velocity as the speed of light (328 yards per microsecond). This means that it takes approximately 6.1 microseconds for radar energy to travel 1 nautical mile, which is approximately 2000 yards per mile; and, because the speed of light (and radar waves) is so great, microseconds (μs) are used for all time determination.

This constant velocity of RF energy is applied in radar to determine range by measuring the time required for a pulse to travel to a target and back. The time lapse between the transmitted pulse and the echo return may be readily determined with the aid of the scope. In our illustration we are using an A-scope, but the principle would be the same for any other presentation with the exception of the starting point of the pulse.

Take a look at figure 4-7 and let us follow one pulse after it leaves the transmitter.

In part 1 of figure 4-7, the transmitted pulse is just leaving the antenna. Notice the transmitted pulse.

In part 2, 61 microseconds later, the transmitted pulse has traveled 10 miles toward the target. The horizontal trace on the scope, however, has reached only the 5-mile mark, that is, half the distance the transmitted pulse has traveled.

In part 3 of the illustration, 122 microseconds after start, the transmitted pulse has reached the target 20 miles away and the echo has started back. Scope now reads 10 miles.

In part 4, 183 microseconds after start of initial pulse, the echo has returned half the distance from the target, and the scope reading is 15 miles.

In part 5, 244 microseconds after the initial pulse, the echo has returned to the receiver, and an echo pip, of smaller amplitude than the initial transmitter pip, is displayed on the scope at the 20-mile mark.

The foregoing are the basic principles of ALL ranging scope determinations. If two or more targets are in the path of the transmitted pulse, each will return a portion of the energy as echoes. The size of the returned echo will depend on several factors, size of reflecting

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ship or object, and so forth. More of this will be covered in detail in later chapters.

Range Markers

As an aid in estimating range on most present-day scopes, you can turn on a control switch labeled MARKERS. Using the PPI-scope for our illustration when you turn on this switch, it causes a series of bright rings to be produced on the PPI screen.

Most PPI's have four range markers as shown in figure 4-8. The range that each marker represents depends upon the search range being used. For example, if the PPI were set on a 10-mile range, each marker would be 5000 yards apart and a target halfway between the third and the fourth marker would be at a range of 7-1/2 miles. On other PPI's the markers are always the same distance apart. In such a case, increasing the range scale also increases the number of markers.

Modern aircraft fly at such terrific speeds, you will find it necessary to use range markers as a reference in estimating range. You will be surprised to find out how accurate you are. Without range markers as a reference it would take too long to estimate.

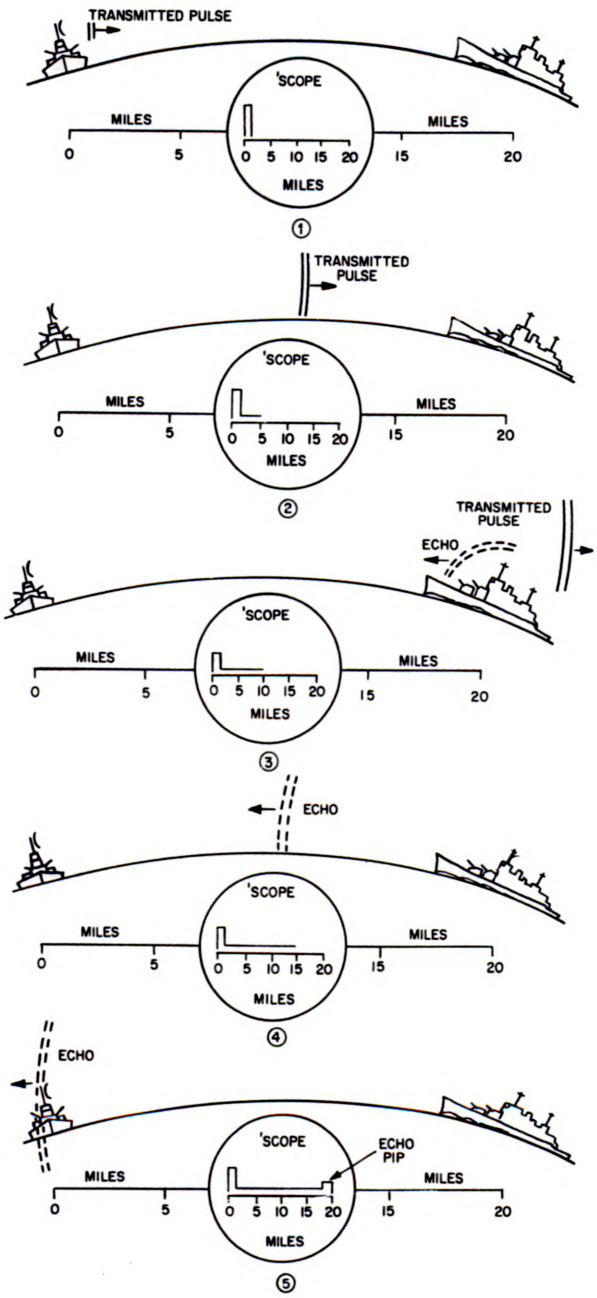

Figure 4-7.—Radar range determination.

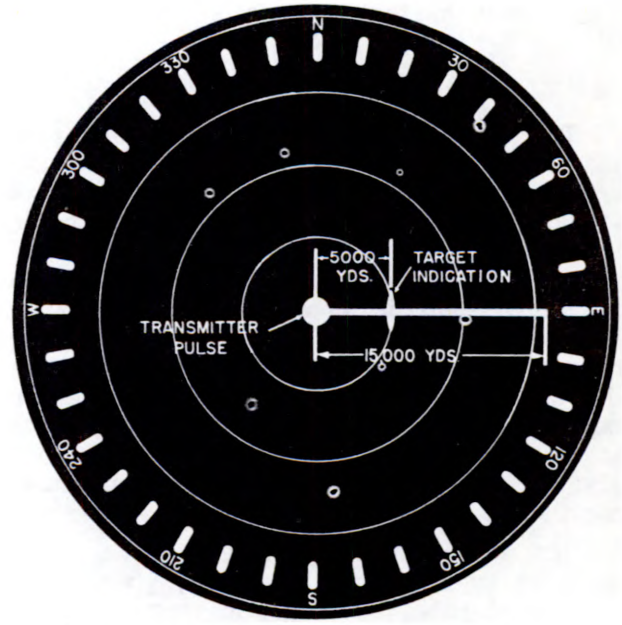

Figure 4-8.—Determining range on a PPI.

Range Ring

Range markers do not provide a very accurate means of reading range on the PPI. Unless the target indication happens to fall directly on one of the range markers, it's easy to see that the operator must estimate the range from the relative position of the target between the markers.

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As stated before, modern aircraft fly at such great speeds that accuracy sometimes must be sacrificed for speed. There will be times, however, when you desire accuracy.

The range ring has been developed to remedy this situation. Like the range markers, it is produced electronically on the face of the PPI. This range ring works on the same principle as the range step on the A-scope. By using a hand crank, the ring can be expanded or contracted so that it can be moved to any distance from the center of the PPI. Thus, the operator can move the range ring into such a position that it bisects the target smear. The range can then be read directly from a mechanical counter connected to the range ring crank. The range ring can be used equally well with any range scale. On some of the more modern repeaters, instead of a ring there is a strobe (sometimes called a "bug") that works on the same principle. The advantage of the strobe or bug is a small bright dot that is an easier and more accurate way of bisecting the target echo.

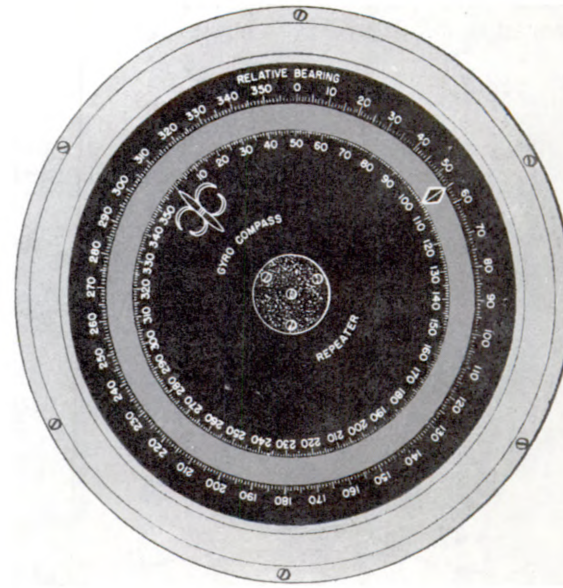

Figure 4-9.—Repeater compass on a repeater.

BEARING DETERMINATION

The bearing (true or relative) of the target may be determined if the direction in which the directional antenna is pointing when the target is picked up is known. Control and indicator systems have been devised that make this possible. One type of bearing indicator, as shown in figure 4-9, is composed of two circles scaled off in degrees. One circle gives true bearing and the other relative bearing. Between the two bearing circles is a small pointer or bug. This bug is connected to the antenna drive motor so that as the antenna rotates, the bug also rotates around the bearing indicator, showing antenna position at all times.

The measurement of the bearing of a target as seen by the radar is usually given as an angular position. The angle may be measured either from true north (called TRUE BEARING), or with respect to the heading of a vessel or aircraft containing the radar set (called RELATIVE BEARING).

The angle at which the echo signal returns is measured by using the directional characteristics of the radar antenna system. Radar antennas are constructed of radiating elements, reflectors, and directors to produce a single narrow beam of energy in one direction. The pattern produced in this manner permits the beaming of maximum energy in a desired direction. The transmitting pattern of an antenna system is also its receiving pattern. An antenna can therefore be used to transmit energy, to receive reflected energy, or both.

The simplest form of antenna for measuring azimuth or bearing is one that produces a single-lobe pattern. The system is mounted so that it can be rotated by hand or by motor at various speeds. Energy is directed across the region to be searched by moving the beam back and forth in azimuth until a return signal is picked up. The position of the antenna is then adjusted to give maximum return signal. When the antenna is trained to produce the maximum pip amplitude on the A-scope, or maximum brightness of the pip on the PPI, the bearing is directly indicated by the position of the bug on the radar's bearing indicator.

Since more than one repeater often is using the same radar information, you therefore can see it is undesirable to stop the antenna. Stopping the antenna also allows electronic countermeasures equipment to measure frequency, PRR, pulse width, etc., more easily. In this case each repeater is equipped to indicate bearing.

Figure 4-10 shows the receiving pattern for a typical radar antenna. In this illustration, relative signal strength is plotted against the

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angular position of the antenna with respect to the target. A maximum signal is received only when the axis of the lobe passes through the target. The sensitivity of this system depends on the angular width of the lobe pattern. The operator adjusts the position of the antenna system for maximum received signal. If the signal strength changes appreciably when the antenna is rotated through a small angle, the on-target position can be selected with greater accuracy. Thus, in figure 4-10, the relative signal strengths "A" and "B" have very little difference. If the energy is concentrated in a narrower beam, the difference is greater and the accuracy better.

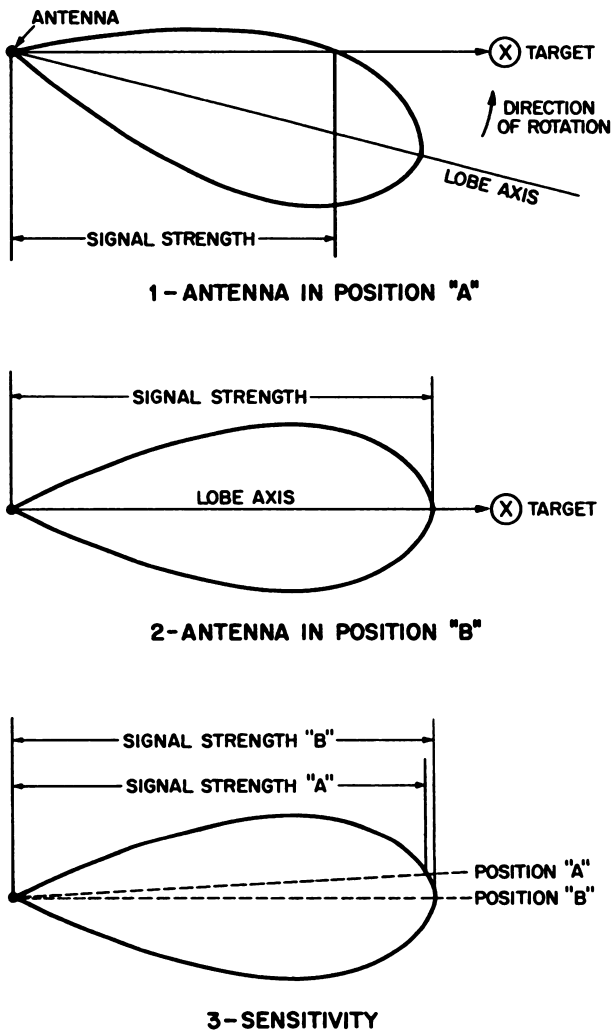

Figure 4-10.—Radar determination of azimuth or bearing.

Bearing Cursor

Not only does the PPI show the range of a target but the bearing as well. The direction or bearing, of a target is indicated by the figure around the edge of the screen (fig. 4-8). This bearing circle is connected to the ship's gyroscope so that the bearings are true. In other words, bearing 000° at the top of the screen points to true north.

Sometimes the gyro input to the bearing circle may fail. In such event, instead of representing true north, 000° represents the bow of your ship and the target bearings would be relative. The bearing would depend on the direction the ship was heading at the time. We'll talk further about true and relative bearings later on in the book. In the meantime remember that in most cases the bearings read from a PPI are true bearings.

Reading bearings from the bearing circle is as difficult as reading range from the range markers. Both operations call for some guesswork on the part of the operator. This would be all right for tracking aircraft but would never do for any degree of accuracy.

To increase the accuracy of bearing reading, a hairline cursor has been inscribed on a plastic surface, and mounted over the face of the PPI. To obtain a bearing the operator merely has to rotate the cursor until it bisects the target. When the hairline bisects the target it also cuts across the bearing circle on the exact bearing of the target. The cursor takes the guesswork out of the PPI.

On most of the modern types of repeaters there is an electronic cursor produced by an electron beam within the scope that is geared to bearing counters. This electronic cursor is operated the same as the hairline. Centering the range strobe also centers the bearing, and both readings can be obtained at the same time from their respective counters. One mistake most operators make with this method is that they have the strobe too bright. To be most accurate the strobe has to be as sharp as is possible for the cursor intensity control (marked RANGE RING on some repeaters) to get it. More about these controls will be learned in the chapter on repeaters.

ALTITUDE DETERMINATION

The remaining dimension necessary to locate completely an object in space can be expressed either as an angle of elevation or as an altitude.

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If one is known the other can be calculated from one of the basic trigonometric ratios. A method of determining the angle of elevation or the altitude is shown in figure 4-11. The slant range (view A, fig. 4-11) is obtained from the radarscope indication as the range to the target. The angle of elevation is that of the radar antenna (view B). The altitude is equal to the slant range multiplied by the sine of the angle of elevation.

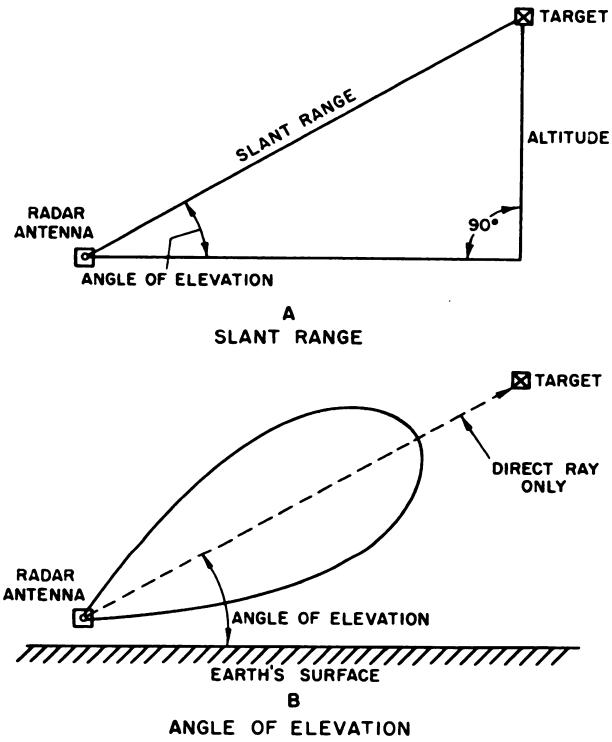

Figure 4-11.—Radar determination of altitude.

In radar equipments with antennas that may be elevated, altitude determination by slant range automatically is computed electronically. In air-search equipments where the antennas do not elevate, altitude is determined by a fade chart.

ALTITUDE DETERMINATION BY AIR-SEARCH RADAR

Early in the use of air-search radars, operators observed that in tracking an airplane, the pip would become smaller and smaller, until it would entirely fade out. The pip would reappear again and gradually grow until it reached its full size.

This strange behavior led the operators to believe that their gear was functioning improperly and puzzled the radar experts for some time. The fades would appear at regular intervals, but not all targets faded at the same range. It was observed that only those airplanes flying at the same altitude fade at the same range. For example, on a particular radar set, all airplanes flying at 5000 feet would fade at 70 miles, 52 miles, 38 miles, and 24 miles, while those at 10,000 feet would fade at 75, 57, 43, and 29 miles. After much study and experimentation, it was discovered that for each particular radar installation, all airplanes flying at a certain altitude would fade at the same range.

It was discovered also that each radar set had different fade areas, but once these areas were determined, they were constant.

The location of these fade areas was determined by sending out friendly airplanes, and directing them to fly at definite altitudes. These areas were plotted on a FADE CHART. The fade areas thus established are constant as long as the antennas and the other parts of the radar gear remain unchanged. This important discovery led to a simple and relatively accurate method of altitude determination.

Figure 4-12 illustrates a fade chart of a certain radar. If an airplane is reported to fade at an 81-mile range, and again in a fade at 43-mile range, it would be located in positions A and B on the fade chart. These two points are at the only altitude an airplane can fly and still fade at 81 and 43 miles. Likewise, an airplane recorded in fade at 60 miles and 30 miles would have to be at an altitude between 6000 and 7000 feet. This should give you an idea of the importance of reporting fades immediately when you are the air-search radar operator.

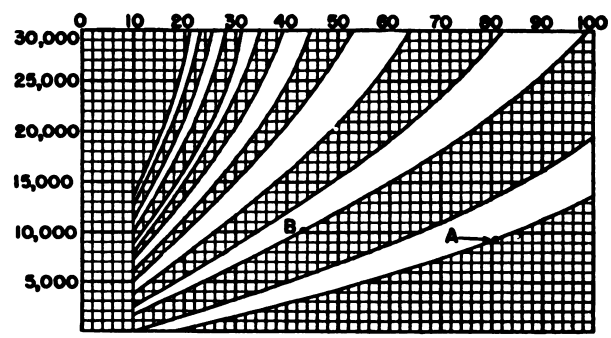

Figure 4-12.—Fade chart.

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Causes of Fade Areas

There are many causes of fade areas, and some are not too well understood. One of the best and simplest explanations is that of alternate paths taken by the radar waves in traveling to the target.

One path travels directly from the antenna to the target, and the other strikes the water and is then reflected to the airplane.

The path of the reflected wave is longer. Since both the direct and reflected waves travel at the same speed, the reflected portion of the wave will arrive after the direct wave has reached the airplane.

Both the direct and reflected portions are wave motions. If the reflected wave arrives in phase with the direct wave, their energies will reinforce each other and thus be stronger; but if the two waves arrive 180° out of phase, they will cancel each other and no returning echo will be observed. A fade area is thus produced when two waves arrive at a point out of time and their energies destroy each other.

Once the position of the areas has been charted, an airplane will reveal its altitude, whenever it crosses two of these fade areas.

After becoming thoroughly familiar with your radar gear, you can predict the ranges at which airplanes will fade. From this ability to predict fade areas, the altitude can be approximated after the target has gone into the FIRST FADE. Be sure to report all fades, as they are of great importance to the aircraft controller.

QUIZ

1. What types of radars will you operate aboard ship?
2. What is the primary function of the surface-search radar?
3. How do fire control radars differ from other types of radars?
4. What are CIC's duties in a fire control problem?
5. What do gunnery personnel have to know about CIC?
6. What information can be obtained from radar?
7. What is the most important function of a radar operator?
8. Why is the lookout important?
9. What is the primary purpose of the A-scope?
10. What causes a pip to appear at the very beginning of the A-scope sweep?
11. What type of presentation has a radial time base line?
12. How does the target appear on the PPI-scope?
13. What is the RHI-scope used for?
14. How is range indicated on the RHI-scope?
15. How long (in microseconds) does it take a radar wave to travel 1 nautical mile (2000 yards)?
16. How are range markers used on the cathode ray tube?
17. Of the two methods of reading range on the PPI-scope, which is the more accurate?
18. How do you take a bearing of a target using the PPI?
19. How may the altitude of a target be determined if the slant range and the angle of elevation are known?

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CHAPTER 5

FUNCTIONAL COMPONENTS

RADAR SYSTEM CONSTANTS

Radar is one of the main sources of information in the CIC. Since the Radarman will rely heavily on his radar equipments for information, it is important that he have an understanding of the various units of radar systems and their capabilities and limitations in order to obtain the most information from the equipment. This chapter will serve to acquaint you with the components of a typical radar system. It will discuss the function of each, and its contribution to the proper operation of the over-all system.

When you first began to study about radar, you learned that radio waves travel through space at about 162,000 nautical miles per second. This is a constant common to all radars.

There are other system constants and definitions that you must know to gain maximum performance from the equipments that you will be operating.

DEFINITIONS

PULSE: A momentary sharp change in a current or voltage, followed almost immediately thereafter by sharp return to normal.

PULSE WIDTH, PULSE LENGTH, or PULSE DURATION: The time that passes between the start and finish of a single pulse.

PULSE REPETITION RATE: The number of pulses transmitted per second.

DUPLEXER: An electronic switching device which automatically switches the antenna from the receiver to the transmitter during the period of transmission and back to the receiver during the period of reception.

INDICATOR: That unit of a radar set by which the data obtained by the set are presented for visual observation.

TRANSMISSION LINE: Any set of conductors used to carry signals or energy from one place to another.

MAGNETRON: An ultrahigh-frequency oscillator tube. Because of its available high peak power, it is often used as a transmitter tube in radar sets.

PEAK POWER: The maximum power at any one moment.

SYSTEM CONSTANTS

While radar systems vary according to their function, they are basically the same. Associated with any radar are certain constants. These constants are chosen for a particular radar system depending upon its tactical use, accuracy required, range to be covered, physical size, and the problem of generating and receiving the signal.

Carrier Frequency

The carrier frequency is the frequency at which the R-F energy is generated. The principal factors influencing the selection of the carrier frequency are the desired directivity and the generation and reception of the necessary microwave R-F energy.

For the determination of direction and for concentration of the transmitted energy so that a greater portion of it is useful, the antenna should be highly directive. The higher the carrier frequency, the shorter the wavelength and so the smaller is the antenna array (pattern) for a given sharpness of pattern, because the individual radiating element is normally a half-wave long. For an antenna array of a given physical size, the pattern is sharper at a higher frequency.

The problem of generating and amplifying reasonable amounts of R-F energy at extremely high frequencies is complicated by the physical construction of the tubes to be used. The common tube becomes impractical and must be replaced by a different tube of special design. Such specially designed tubes are normally much smaller than regular tubes. One of the problems when reducing the size of a tube is the reduction in the power rating of the tube.

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Carrier frequencies may be 100 megacycles and above.

Pulse Repetition Rate (PRR)

The pulse repetition rate of a radar is the number of times per second the transmitter is caused to send out pulses of R-F energy. Enough time must be allowed between pulses for an echo to return from any target within the maximum working range of the radar; therefore, the maximum range desired determines the highest PRR that can be used. The persistence of the indicator screen and the rotational speed of the antenna determine the lowest PRR that can be used.

Enough time must be allowed between each transmitted pulse for an echo to return from any target located within the maximum workable range of the system. Otherwise, the reception of echoes from more distant targets would be blotted out by succeeding transmitted pulses. For this reason the maximum range of a given equipment depends on the pulse repetition rate, provided the peak power is enough to return a usable echo. The maximum range desired when designing the equipment fixes the highest PRR that can be used.

When the antenna system is rotated at a constant speed, the beam of energy strikes a target for a relatively short time. During this time a sufficient number of pulses of energy must be transmitted in order to return a signal that will produce the necessary indication on the scope. For example, an antenna rotating at 6 RPM, having a PRR of 800 PPS, will produce about 22 pulses for each degree of antenna rotation. The persistence of the screen and the rotational speed of the antenna therefore determine the lowest PRR that can be used.

A low PRR has the advantage of permitting very high peak power with reasonably low average power. This permits the use of small vacuum tubes and other light equipment. If the transmitter is pulsed at 60 cycles a second, a very simple keyer may be used. The powerline frequency is 60 cycles and so the keyer may be controlled directly from the powerline.

A disadvantage of a low PRR is the ease with which a small pip may be hidden. With a 60-cycle PRR, the grass or fuzziness along the baseline of the scope may be larger than the pip. In such a condition, small target echoes may be lost.

With a high PRR, each blade of grass is smaller and a small pip will not be as easily lost in the grass.

A low PRR is used for air search since you must have a long period of time to permit the pulse to go out and the echo to return.

Pulse Width (PW)

The pulse width (or pulse length) is a measure of the length of each transmission or pulse of energy in units of time, and is usually expressed in microseconds. The minimum range at which a target can be detected is determined largely by the pulse width. The range resolution (difference in range between two targets on the same line of bearing that must exist in order for the radar to tell the difference between them) also depends on the pulse width.

If a target is so close to the transmitter that the echo is returned to the receiver before the transmitter is turned off, the reception of the echo will be masked by the transmitter pulse. For example, a pulse width of 1 microsecond will have a minimum range of 164 yards, meaning that a target within this range will not show because it will be "blocked out" on the screen. In this respect, equipments for "close-in" ranging or navigation work use pulses of about 0.1 microsecond. For long-range detection equipment the pulse width is normally from 1 to 5 microseconds.

Modern radar receivers have recovery times measured in hundredths of a microsecond, and targets that are at a range just slightly greater than 1/2 the transmitted pulse width will be displayed. Theoretical minimum range is PW x 164 yards and varies from actual minimum range only by receiver recovery time. The minimum range of a radar using a 2 microsecond pulse width will be approximately 2 x 164 = 328 yards.

Another advantage is that a short pulse permits a more accurate range. The pip is narrow and range indications are sharper.

The problem in radar detection is to have a signal to noise ratio that will allow the echo to be seen through the grass on the radar screen. The use of a long pulse allows a greater average signal strength to be returned in the target echoes. This enables the radar receiver to do a better job, and weaker echoes may be detected.

Power Relationship

The power contained in each pulse of radiated energy is termed the PEAK POWER of the radar.

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Power is usually measured as an average value over a relatively long period of time. Since the radar is delivering power (transmitting) for a very short period of time, and resting for a long period, the average of the power delivered over a period of one complete cycle of operation is very low compared to the peak power. Peak power is the useful power of the radar. High peak power is desirable to produce a strong echo over the maximum range of the equipment. Low average power permits the tubes and components to be made smaller and more compact. Average power varies directly as the peak power, pulse width, and pulse repetition rate. It can be expressed mathematically as:

Average power = peak power x PW x PRR.

FUNCTIONAL PARTS OF A RADAR

Radar systems now in existence vary greatly as to detail. They may be very simple, or if more accurate data are required, they may be highly refined. The principles of operation, however, are about the same for all systems. Thus, a single basic system can be thought of in which the component parts work about the same in all specific equipments. The varying details are due to a choice of certain circuits. The functional breakdown of the pulse-modulated radar system resolves itself into eight essential components as shown in figure 5-1.

POWER SUPPLY

The power supply furnishes all the A-C and D-C voltages necessary for operating the components.

TIMER

The function of the timer is to ensure that all circuits connected with the radar system operate in a definite time relationship with each other and that the interval between pulses is of the proper length.

The circuits in a radar set that control and synchronize the operation of the several components of the set are known as timing circuits. Sometimes they are assembled in a separate unit called a timer, synchronizer, keying unit, modulation generator, or timing generator. Timing circuits, together with other circuits of a set, may be built into the same unit, such as the indicator unit or range unit.

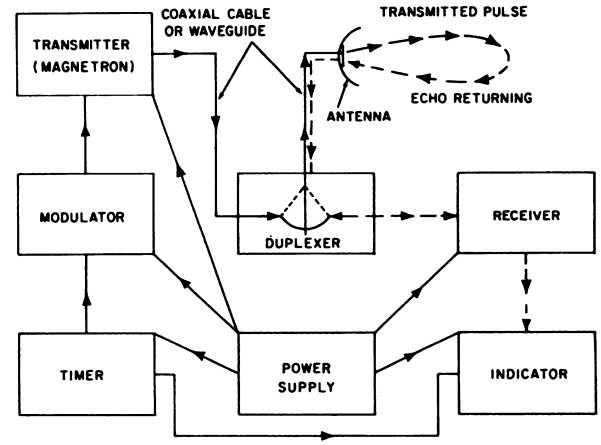

Figure 5-1.—Fundamental radar system.

Radar systems may be divided into the following two classes with respect to the manner in which the timing functions are carried out: (1) master oscillator systems, and (2) self-synchronous (self-timing) systems.

In the master oscillator type the timer determines the pulse repetition frequency and provides trigger and gate pulses for controlling the entire system.

In the self-synchronous type a sync pulse is taken from the transmitter to start the other trigger and gate pulses for the system.

TRANSMITTER

The transmitter in a radar system is basically a simple oscillator—except for two important differences. The differences are that (1) a radar transmitter puts out radio waves of much higher frequency; and (2) a radar transmitter has a much higher power output than an oscillator.

There are reasons why a much higher frequency and a much higher power output are required in a radar transmitter. The more power that is sent out in the radar beam, the stronger will be the echoes and the greater the detection range. The higher the frequency, the more easily the radar waves are reflected and the smaller is the antenna required to form a radar beam of any desired shape.

Strangely enough, some radar transmitters consist of only one oscillator tube. There is no need for buffers, frequency multipliers, and power output tubes. Some radar oscillator tubes are capable of putting out a million watts peak power and yet are only about five times the size

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of an ordinary vacuum tube. Compare this with a 50,000-watt commercial radio transmitter which is often larger than an entire radar installation.

How does a single oscillator tube, that you can almost put in your pocket, generate a million watts of power? The secret is that this single oscillator tube, a magnetron, transmits the high level of energy in the form of extremely short pulses and is turned off between pulses for comparatively long intervals. A magnetron is nothing more than a fancy diode which works in a powerful magnetic field. The diode is placed in the magnetic field produced by a permanent magnet. (See fig. 5-2.)

A magnetron consists of a cylinder-shaped plate with a cathode running down the central axis of the cylinder. When there is no magnetic field, the electrons flow directly from the cathode to the plate (electron path (1) in fig. 5-2). When a weak magnetic field (electron path (2), fig. 5-2) is applied, the electron paths become curved. As the magnetic field becomes stronger (electron paths (2), (3), (4), and (5), fig. 5-2), the electron paths become more and more curved. Finally, the paths become so curved that the electrons are moving in closed circular orbits that miss the plate entirely, and no plate current flows. The plate is a copper block, the internal surface of which is separated into a number of segments (parts) by holes in the block that serve as tuned circuits. As the electrons move in circles past the plate segments, they induce currents electrostatically in the walls of the holes. The energy of the magnetron output pulse is contained in the field associated with these currents. The smaller the circles the electrons make, the higher is the frequency of oscillations. The frequency depends on the size of the cylinder, the strength of the magnetic field, and the difference in potential between the cathode and plate.

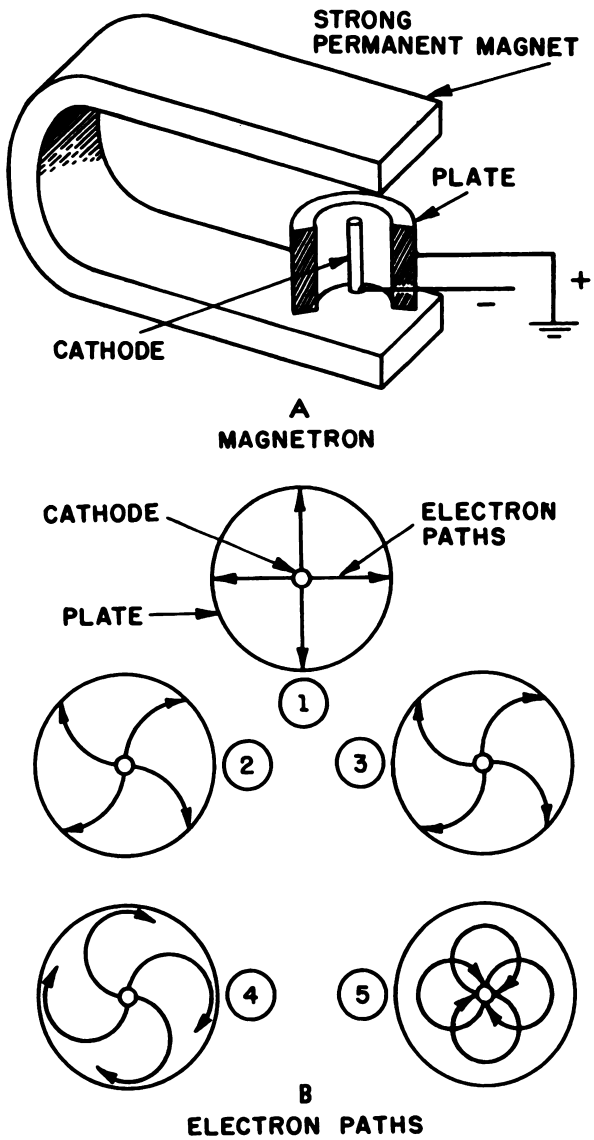

Figure 5-2.—Simplified diagram of a magnetron.

Radio waves of such high frequencies are known as microwaves. This microwave energy is coupled out of the magnetron by means of a loop or probe; it is then transmitted to the antenna via a waveguide to be sent out into space.

Before we go on, let's make sure you understand how oscillators work. Their action is not easy to understand because it is impossible to see exactly what happens. However, there are some commonplace things you can observe which will help you understand how the oscillator works.

One of the first oscillators you ever came into contact with was the rope swing in your own backyard. The easiest way to understand how it worked is to recall what it did.

First, the swing would not start its back-and-forth movement unless you gave it a push. Once the swing was started, it would appear to coast back and forth in an ever-decreasing arc until it finally came to rest in its original position. In order to keep the swing moving back and forth through an arc of constant length, you had to give the swing an occasional push—just strong enough and at the right time. That simple rope was an oscillator.

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One of the outstanding features of your swing was the rate at which it moved back and forth. When you were pushing your swing, you did not realize that the time intervals between pushes were exactly alike. It did not make any difference whether you gave the swing a gentle touch, or a mighty shove; it came back to you in exactly the same length of time.

You probably never did count the number of shoves you gave each minute, but for one particular swing this number was always the same. Suppose the number of pushes a minute were 20. You would be pushing at the rate of 20 a minute. The frequency with which the swing is moving back and forth is 20 times a minute.

If you shortened the ropes of your swing, it would move back and forth more rapidly. The rate or frequency would be higher. If it were possible to keep shortening the ropes of the swing, the frequency would become higher and higher, until it would be impossible to count the swings.

The frequency at which the electrical swings of a radar oscillator move back and forth is so fast that it is impossible to count them. Most radar oscillators have frequencies above 200,000,000 cycles per second.

As you progress in the study of radar you will find that some models of radars use vacuum tubes for oscillators, and some use magnetrons. The difference is in the frequencies the transmitter is to transmit. (The cutoff frequency cannot be disclosed here.) In general, low-frequency radars use vacuum tube oscillators.

So far, you have seen how extremely high-frequency radio waves can be generated by a single oscillator tube, the magnetron. Now you will want to know more about how a small tube can possibly generate as much as a million watts of power.

The answer is simple. In the case of a typical radar, the tube generates a million watts only for the 1 microsecond that it is turned on. This would be an average power output of 1 watt per second, if only 1 pulse. Since there are 650 pulses per second, the average power output is 650 watts.

In normal operation of our example radar system, the magnetron must be turned on for one-millionth of a second and then turned off. Plate voltage is kept off the magnetron for about one six-hundred-fiftieth second and then applied again for one-millionth of a second. In this way you can get 650 1-microsecond pulses every second. (See fig. 5-3.)

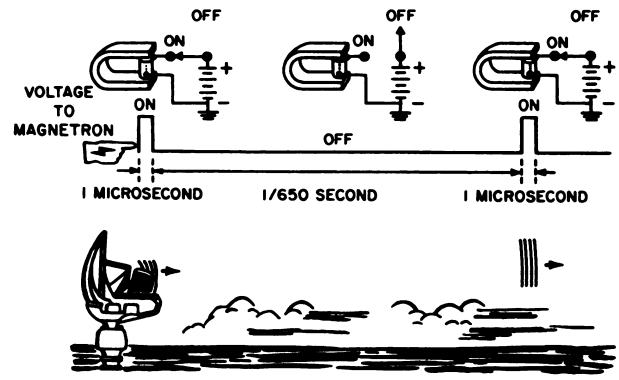

Figure 5-3.—Applying positive plate voltage to the maggie for 1 microsecond.

In actual practice, positive voltage is not applied to the plate of the magnetron. Instead, the plate is connected to ground and a high negative voltage is connected to the cathode. The net result is the same: The plate is positive with respect to the cathode. The operation is exactly the same as if the cathode were grounded and the plate were made positive.

THE KEYER OR MODULATOR

Can you turn a modulator switch on and off at the rate of 60 times a second? You can? Well, try this trick: Turn it on, allow the radar to run for 2 microseconds, turn it off for 1598 microseconds, then turn it on again. Repeat this process 625 times each second. Obviously impossible. But, in a radar set there is a device known as the keyer or modulator that does exactly that thing. The keyer turns the transmitter on, permits it to run for a few microseconds, turns it off, keeps it off for several thousand microseconds, then turns it back on, repeating this process over and over at a rate which may vary from 600 to 1000 times a second according to factory settings.

The modulator turns the transmitter on for example 650 times a second. (This number is not the same for all radars.) This is called pulse repetition rate or frequency. The modulator accomplishes this by putting out a high negative voltage pulse a few microseconds wide, repeated 650 times per second. This voltage is connected to the magnetron cathode, and causes it to oscillate whenever the high negative voltage peak comes along. The special circuits making

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up the modulator are the repetition rate oscillator, overdriven amplifier, differentiating circuit, cathode follower, and blocking oscillator.

The actual working of these special circuits is the responsibility of the ET's aboard your ship. In order for you to understand radar more thoroughly, we will define the functions briefly for you. Figure 5-4 shows these special circuits as they would appear in the modulator.

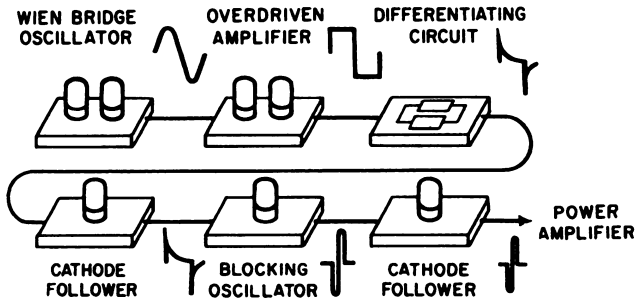

Figure 5-4.—Special circuits that are used in a radar modulator.

Repetition Rate Oscillator (or Wein Bridge Oscillator)

This is a generating type of special circuit. It is used in the radar modulator to establish the repetition rate at which the radar transmitter is to be turned on. The repetition rate oscillator puts out a sine wave whose frequency and amplitude are very stable.

Overdriven Amplifier

This is a pulse reshaping type of special circuit. It is used in the radar modulator to convert the sine wave from the oscillator to a square wave at the same frequency. The overdriven amplifier makes use of cutoff and saturation limiting to square off the sine wave peaks.

Cathode Follower

The cathode follower is a connecting type of special circuit. It is presented out of the order in which it actually appears in the modulator to permit you to get a better picture of the differentiating circuit action. The cathode follower is used as a buffer between circuits of high output impedance and low input impedance.

Differentiating Circuit

This is a reshaping type of special circuit. In the modulator it is used to form a trigger voltage whose frequency is the same as the repetition rate determined by the oscillator. The differentiating circuit forms positive and negative triggers which coincide with the leading and trailing edges of the square wave that is put into it.

Blocking Oscillator

The blocking oscillator is a generating type of special circuit. When triggered by the differentiating circuit output, the blocking oscillator in the radar modulator drives a power stage to develop the high voltage necessary to turn the radar transmitter on.

ANTENNA

In order for the radio wave energy from the magnetron to be of any use, it must be fed to a transmitting antenna where it can be beamed in any desired direction. The purpose of the radar antenna is to send out the radio waves in a concentrated beam rather than let the waves escape equally in all directions as is often done with communication antennas.

The antenna systems used with radars are composed of three major units: the antenna reflector unit, the duplexer or reprod, and the transmission lines. Let us discuss these in the order in which they appear.

A radio-frequency current flowing in a wire of a certain length can produce electromagnetic fields that may be set free from the wire and sent out into space. An understanding of how these electromagnetic waves are set free will help you understand the operation of a radar antenna.

The principles of the radiation of electromagnetic energy are based on the laws that a moving electric field creates a magnetic field and a moving magnetic field creates an electric field. The created field (either electric or magnetic) at any instant is in phase in time with its parent field, but is perpendicular to it in space. These laws hold true whether or not a conductor is present.

Actually the electric and magnetic fields are perpendicular to each other and perpendicular to the direction of motion through space. Their relative directions can be found mathematically, but for the present purpose it is enough to give a "right-hand rule" that shows the directions. This rule states that if the thumb, forefinger, and middle finger of the right hand are held out

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with the thumb up, the forefinger pointed away from you, and the middle finger pointing straight out to the left, then, if the thumb points in the direction of the electric field and the forefinger in the direction of the magnetic field, the middle finger will point in the direction in which the wave is sent out.

In view A of figure 5-5, a piece of wire is cut in half and attached to the terminals of a high-frequency A-C generator. The frequency of the generator is chosen so that each half of the wire is one-fourth the wavelength corresponding to the generator frequency. The result is a common type of antenna known as a dipole.

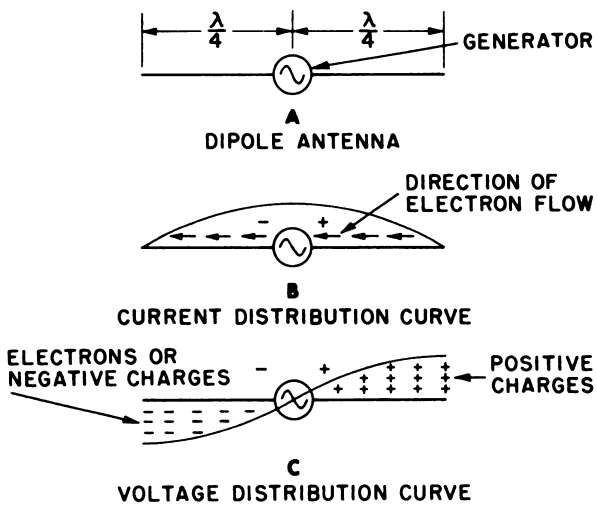

Figure 5-5.—Dipole antenna showing current and voltage distribution.

At a given instant, the right terminal of the generator is positive and the left terminal is negative. Because like charges repel, electrons will flow away from the negative terminal as far as possible, while the positive terminal will attract electrons to it. Figure 5-5, view B, shows the direction and distribution of electron flow. The distribution curve shows that most current flows in the center and none at the ends. There is no place for the electrons to go when they reach the end of the wire; therefore the current at the ends must be zero. The current variation at any point in the antenna is sinusoidal with respect to time if the generator voltage has sine waveform. The relative current distribution is also sinusoidal with respect to the antenna length. Thus, an R-F ammeter inserted near the center of the antenna will indicate a relatively large effective current, and one inserted near the end will indicate a low effective current. The relative current distribution over the antenna will always be the same no matter how much or how little current is flowing, but the current amplitude at any given point on the antenna will vary directly with the amount of voltage developed at the generator terminals.

The generator (transmitter) voltage starts the flow of antenna current. The action of the antenna is like that of a capacitor. When a capacitor becomes fully charged, its voltage is maximum and charging current ceases. In figure 5-5, C, the antenna voltage near the ends is maximum at the instant that the charging current is zero. Although no current flows at this instant, there is a maximum number of electrons at the left end of the antenna and a least number at the right end. Most of the charges are at the ends trying to get as far from the generator terminals as they can (like charges repel). The antenna voltage, like the antenna current, varies sinusoidally with respect to time. Also the antenna voltage varies sinusoidally with respect to the antenna length. Thus, an R-F voltmeter connected between ground and one end of the antenna indicates a relatively large effective voltage. As the end-probe is moved toward the antenna center, the effective voltage is decreased to a low value. The antenna has both distributed inductance and capacitance and acts like a resonant circuit. At the center the current and voltage are in phase with each other; between the center and the ends they are out of phase.

Induction Field

An alternating current flows in the antenna; therefore an alternating magnetic field, H, is set up around the antenna, as in part A of figure 5-6. Alternate positive and negative charges also appear on the antenna, causing an electric field (E in fig. 5-6, view B) to be set up. This field is represented by lines of force drawn between the positive and negative charges (fig. 5-6, B). The arrowheads indicate the direction a unit positive charge would move at that point. Because the current and charges that produce these fields are 90° out of phase, the two fields must also be out of phase by 90°. Thus, in spite of the fact that they are 90° out of phase, these fields do not make up the radiated electromagnetic field that passes through space from the transmitting antenna to the receiving antenna. The magnetic and electric components of the radiated field are in phase

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with each other. The energy contained in the induction field cannot be detached from the antenna. The amplitude of the induction field energy varies inversely as the square of the distance from the antenna, and as a result its effect is local.

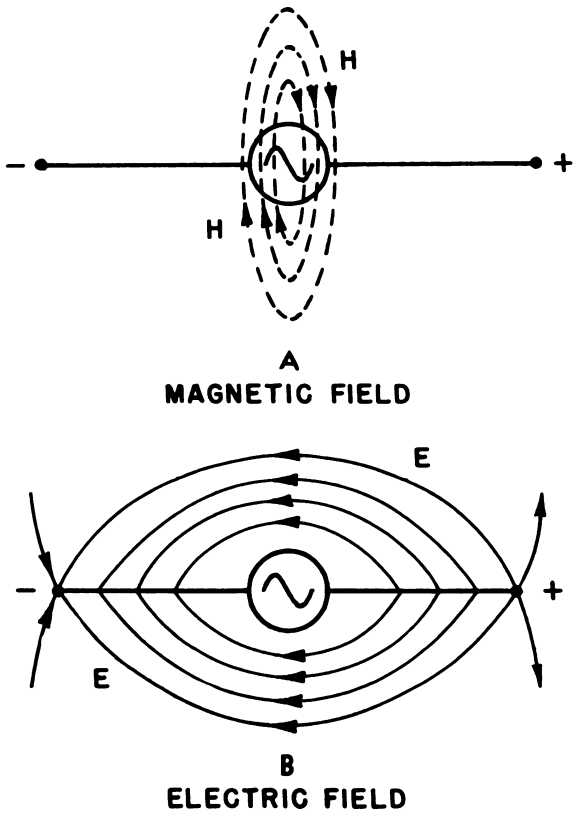

Figure 5-6.—Fields around an antenna.

Radiation Field

Although both a magnetic and an electric field are radiated into space at the same time, only the electric field will be considered at this point. The charges producing the electric field are constantly moving from one end of the antenna to the other as the polarity of the voltage at the generator changes. At one instant, one end of the antenna is positive; an instant later the antenna is uncharged. A negative charge next appears where the positive charge was. Then the antenna is again uncharged, and the whole cycle repeats.

In figure 5-7, view A, electric flux lines are drawn between positive and negative charges. An instant later (fig. 5-7, view B), the antenna is nearly discharged, as the charges approach each other, thus bringing together the two ends of the flux lines associated with them. When the charges do touch, they seem to disappear, and their flux lines that represent the induction field do disappear. Some flux is repelled by other lines nearer the antenna and, as in figure 5-7, view C, the repelled flux lines are left with their heads touching their tails. A closed electric field will thus be created without an associated electric charge.

An instant after the independent field has been formed, the antenna is charged again in the opposite direction and produces lines of force that repel the recently formed independent electric field. Figure 5-7, C, shows that the repelling field is of the proper polarity to do this. The radiated field is forced away from the antenna at the speed of light.

As previously stated, a moving electric field generates a perpendicular magnetic field in phase with it. Because the radiated electric field is

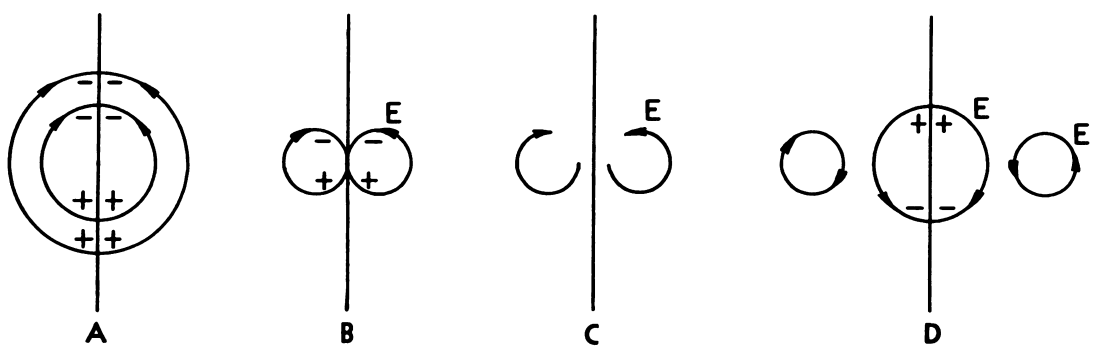

Figure 5-7.—Creation of closed electric flux lines on a half-wave antenna.

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moving, it generates a magnetic field in accordance with this principle. The result is a radiated electromagnetic field that can travel great distances and deliver a usable part of its energy to a receiving antenna, as in the case of radio. In the case of radar, a pulse is radiated into space and upon striking a target, a portion of the energy is reflected to the antenna.

Reception

As the reradiated (reflected) electromagnetic field passes through a conductor, some of the energy in the field will set electrons in motion in the conductor. This electron flow forms a current that varies in accordance with the variations of the field. Thus, a variation of the current in a radiating antenna causes a similar varying current (of much smaller amplitude) in the conductor of the receiving antenna. Any intelligence being produced as current in a transmitting antenna will be reproduced as current in a receiving antenna. The characteristics of good receiving and transmitting antennas are similar, so that a good transmitting antenna is also a good receiving antenna.

Directional Antennas

So far, you know that an antenna is a conductor or system of conductors which serves to send out or receive energy in the form of electromagnetic waves. In its elementary form an antenna or aerial may be simply a length of elevated wire like the common receiving antenna for an ordinary broadcast receiver. However, for radar work, other factors make the design of an antenna system more complex. For example, a single vertical dipole radiates radio waves equally well in all directions in a horizontal plane. Since the current is greatest at the center of a dipole, maximum radiation will be at this point and almost no radiation occurs at the ends. If this antenna could be isolated completely in free space, its radiation would be at right angles to the plane of the conductor and would encircle the conductor completely. A look at figure 5-8, view A, will tell you that this type of antenna could never be used as a radar antenna to tell direction, because the shape of the radiation pattern would resemble a doughnut with the antenna wire passing through its center. The field strength is the same in any compass direction.

If a horizontal dipole is used, the free space pattern of figure 5-8, A, and C, applies if it is rotated 90°. Thus, figure 5-8, B and D, shows the doughnut pattern for a horizontal plane—still not suitable for determining direction.

Directional effects can be produced, however, by the use of two or more dipoles so spaced and phased that radiation from the dipoles adds in some directions and cancels in other directions. For example, figure 5-9 shows that when two antennas, A and B, half a wavelength apart, are excited in phase, their radiation is mostly along a line at right angles to their plane.

The reason for this directional effect is as follows: Since the currents of antennas A and B are equal and in phase, the fields radiated at any instant are identical in polarity, phase, and amplitude. However, by the time energy from A reaches B, because of the time required for energy to travel half a wavelength, the phase of the energy in the field at B has changed by half a wavelength or 180° and the two fields almost cancel. The same condition applies to energy sent out from B reaching A. Thus, the radiation in the plane of the two antennas is reduced to a tiny value. At the same time, the radiation fields of the two antennas, arriving at any point at right angles to the plane of the antennas, are in phase and therefore add, producing a stronger radiation field at that point. This type of two-element array has a bidirectional field pattern.

If radiation is wanted in only one general direction, a different element arrangement must be used, or the elements must be fed out of phase.

If two identical dipoles are placed side by side, spaced a quarter-wavelength apart, and driven with equal currents having a phase angle of 90°, the radiation pattern will be in one direction. (See fig. 5-10.) By the time the radio wave leaving antenna A reaches antenna B, the wave leaving B will have the same phase so that the two waves add to produce maximum radiation to the right. However, by the time the radio wave leaving antenna B reaches antenna A, the wave leaving antenna A will be 180° out of phase, causing complete cancellation to the left. At other angles the waves add to give intermediate values as shown in part A of figure 5-10 for the vertical plane and part B of the illustration for the horizontal plane. The solid surface pattern of figure 5-10, part C, gives a better idea of the radiation in other directions.

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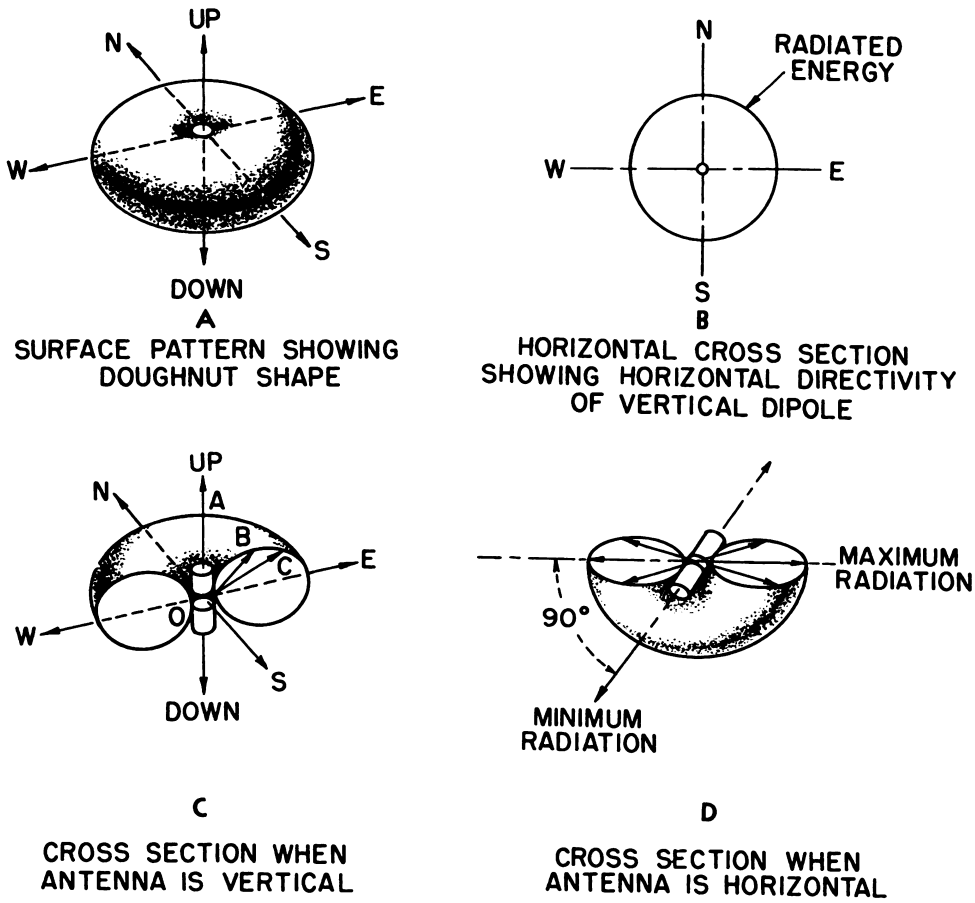

Figure 5-8.—Radiation pattern of a dipole.

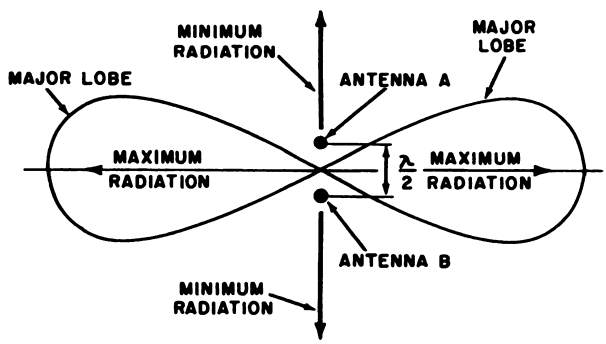

Figure 5-9.—Horizontal radiation pattern of two vertical antennas spaced half a wavelength apart and fed in phase.

Notice in figure 5-11, A, that the shape of the wave is changed greatly by placing a second dipole at a distance one-half wavelength from the first.

If three dipoles are placed in line one-half wavelength apart, the antenna pattern appears as in figure 5-11, B. When you add more dipoles, the pattern takes the shape of view C of the illustration.

As indicated in figure 5-11, the lobe becomes narrower and sharper as more and more dipoles are added. Also notice in figure 5-11, view B, two small additional side lobes or minor lobes appear; in view C there are four. These minor lobes are present with certain types of radar antenna arrays, and are a source of trouble to the operator. They may hide close-in targets, or cause you to get false bearings, so you must be on guard constantly to recognize them.

The lobes shown in figure 5-11, C, are not practical for telling the direction of the target, because you have only a 50-50 chance of guessing which bearing the target is actually on.

If a second row of dipoles is placed directly behind and at the correct distance away from the

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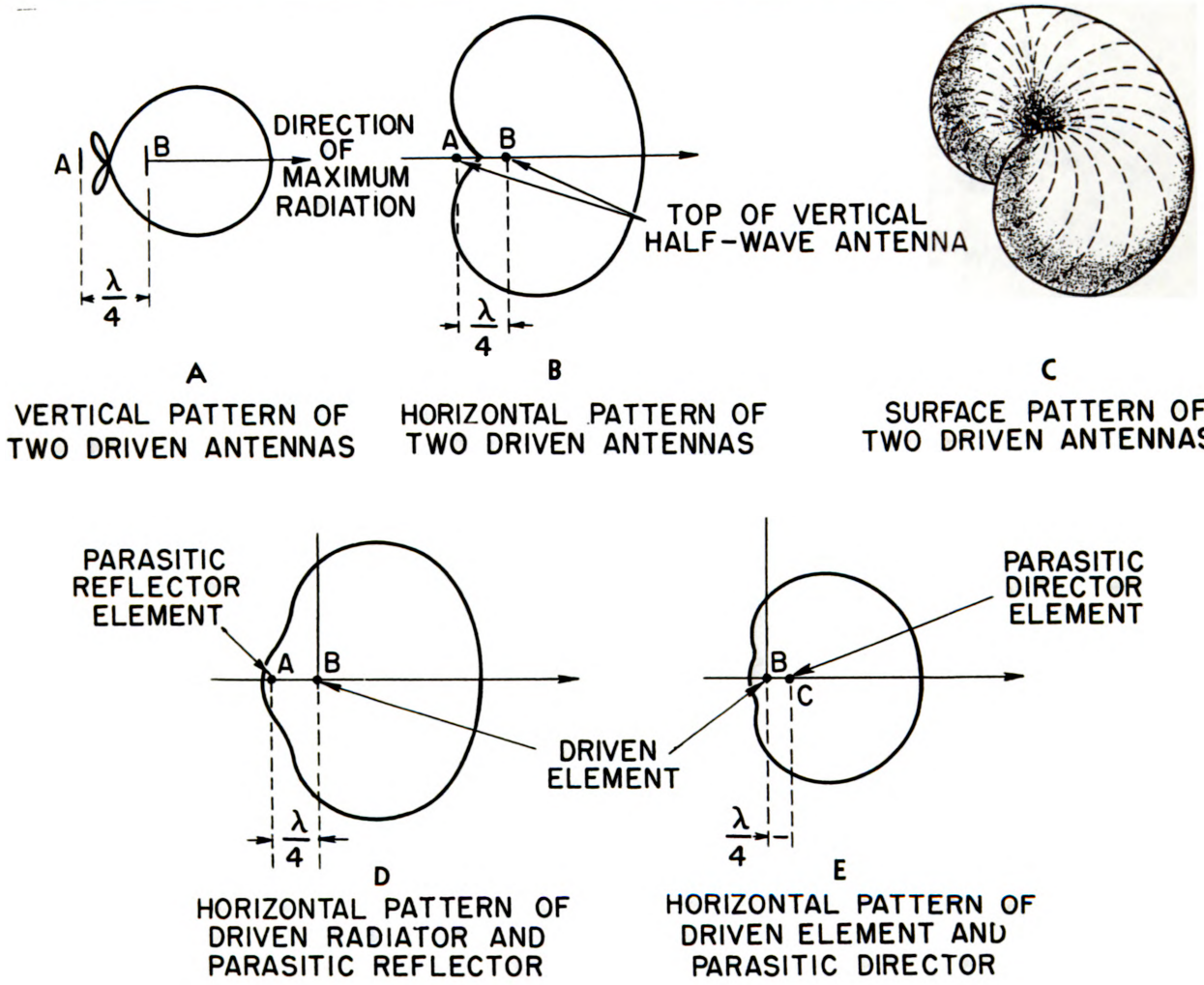

Figure 5-10.—Radiation pattern of two antennas used to obtain maximum radiation in only one direction.

first row the lobe to the rear is completely cut off, and the forward lobe is made stronger.

Notice in figure 5-12 that one row of dipoles forms the antenna and the second row the reflector. The complete assembly of dipoles is known as the curtain array, or bedspring antenna (fig. 5-13).

By a combination of dipoles, connected in the correct electrical manner, it is possible to produce a lobe that is in one direction. When the lobe is pointed at the target, the echo will be strongest, and you will know that your target is located in that direction. This antenna, as illustrated in figure 5-13, is used with air-search radar. The

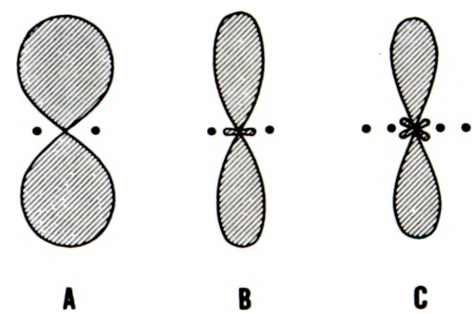

Figure 5-11.—How dipoles produce lobes.

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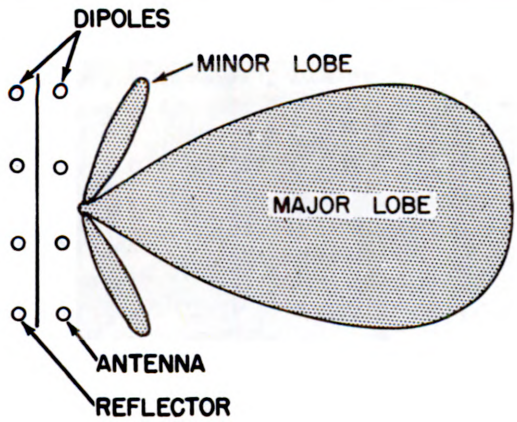

Figure 5-12.—Dipoles and reflectors.

size of the antenna is not the same for all types of gear, but the principle of operation is the same. In this antenna, the reflecting dipoles have been replaced by a series of rods. However the principle of reflection does not change.

Types of Radar Antennas

There are many types of antennas used with military radar systems. Some of the more common types with which we will be concerned will be discussed, along with their characteristics. In general the term "antenna" is applied to the entire antenna array, which may include the actual radiating element and its associated directors and reflectors. Actually, the antenna is

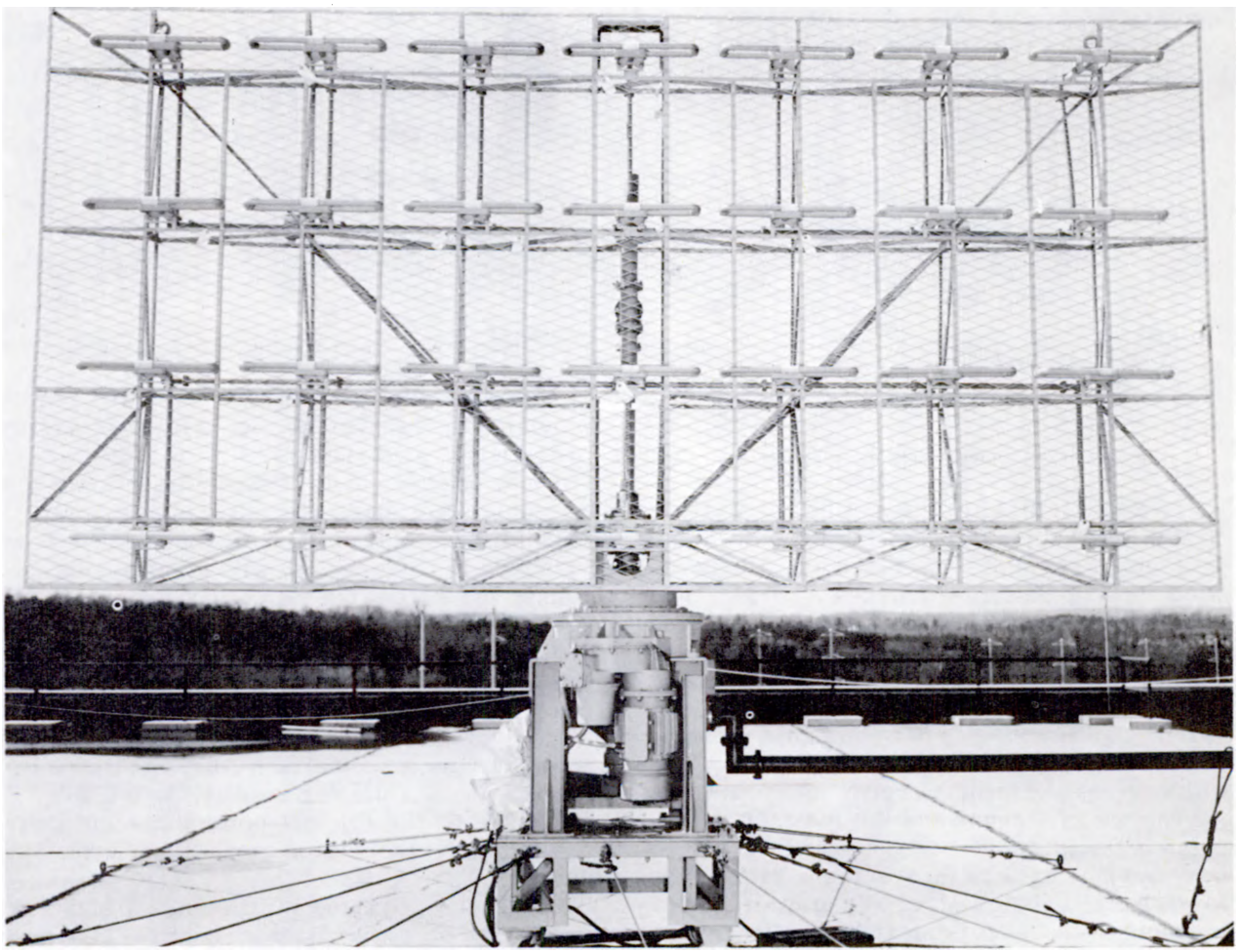

Figure 5-13.—Curtain or bedspring array.

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the radiating element, and may be in the form of a dipole (a conductor which is one-half wavelength long at the carrier frequency of the radar) or a feed horn arrangement (the flared termination of a waveguide, which will be discussed separately).

BEDSPRING: The bedspring antenna consists of a stacked dipole array with an untuned reflector. It is so called because of its resemblance to a bedspring. The more dipoles that are used or stacked in one dimension (horizontal, for example), the more narrow the beam of radiated energy becomes in that same plane.

LINEAR PARABOLIC: The linear parabolic type of antenna consists of a stacked dipole array in one area, backed by a linear parabolic reflector. The width of the beam is again determined by the number of stacked dipoles, the linear parabolic reflector concentrating or focusing the beam in the other direction. One of the principal uses of linear parabolic-type antennas is in fire control radar. (See fig. 5-14.)

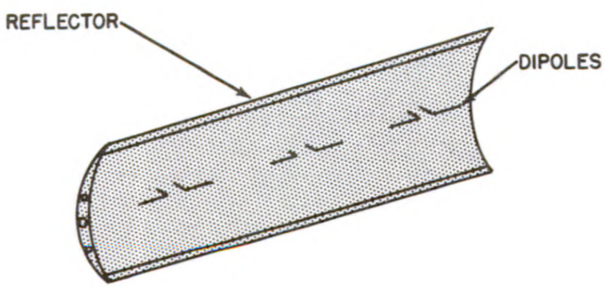

Figure 5-14.—Linear parabolic-type antenna.

PARABOLOIDAL: The paraboloidal antenna consists of a dipole or feed horn radiator and a paraboloidal or dish-type reflector. The paraboloid type of antenna produces a narrow beam in all directions. This type of reflector is used in fire control radars, since fire control radars need highly directional radiation patterns to ensure strong echoes and also to reveal the exact bearings of the targets. The antennas employed usually consist of movable reflectors equipped with devices for feeding energy into them.

The use of antenna assemblies such as these is one of the advantages of operation in the microwave region of the radio spectrum. Microwaves have characteristics which are similar in many respects to those of visible light. If a light source is placed at the focal point of a parabolic (dish-shaped) mirror, a concentrated beam is produced, and the width of the beam depends on the diameter of the mirror. Similarly, if a metal reflector of the same general shape is used instead of the mirror, and if a source of microwave radiation is placed at the focal point, the metal reflector sends out a beam of electromagnetic waves. The width of the microwave beam also depends on the diameter of the reflector—for a given wavelength, the wider the reflector, the narrower is the projected beam.

The concentration of microwave energy is illustrated in part A of figure 5-15. As shown in part B, the beam can be directed in desired paths by the use of special reflector shapes.

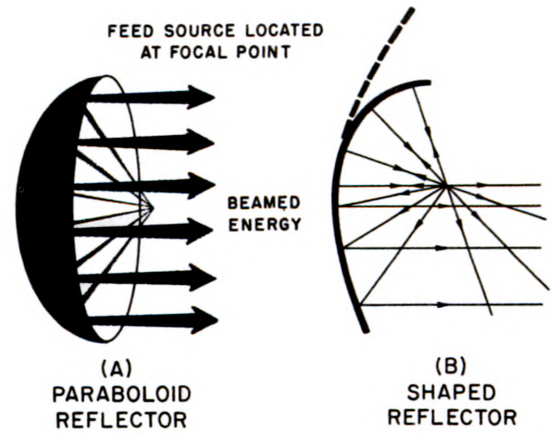

Figure 5-15.—Action of reflector on microwaves.

Because the lobe produced by the paraboloidal reflector (part A, fig. 5-15) is too narrow and sharp, it is not used with most air- or surface-search radars. Its chief function is with fire control radar, aircraft radar, or radars built for a special function. If the antenna shown in figure 5-15 were used with a surface-search radar, the roll of the ship might cause the lobe to miss the target. The very narrow vertical beam may pass directly over the ship or target, or strike into the water and be uselessly reflected into space.

To get increased vertical height, a simple change is made in the reflector, and the barrel stave antenna reflector results. As indicated in figure 5-16, the top and bottom are cut away, leaving only the center part of the reflecting surface.

The lobe produced by the barrel stave reflector is still narrow horizontally, but since there is no surface to restrict its vertical height, the lobe will become a high vertical beam. The height of the lobe is great enough so the roll of

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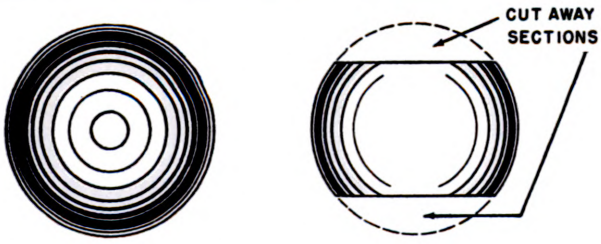

Figure 5-16.—Modification to increase vertical spread.

the ship will not cause the beam to miss the target.

An antenna using the barrel stave reflector is shown in figure 5-17. In this type of antenna the radiating element is the open end of a waveguide, although a dipole antenna would serve the same purpose. With waveguide feed, the energy is sprayed against the reflector like a stream of water from a hose. The reflection is exactly the same as it would be if the barrel stave were used with a dipole antenna.

Figure 5-17.—Antenna employing barrel stave reflector.

Two methods of feeding microwave energy into antenna reflectors are shown in figure 5-18. In view B, two dipoles are located at the focal point of the dish and receive energy from a waveguide. The length and position of the dipoles is such that they radiate to the left, sending energy in a cone-shaped pattern which misses the opening of the waveguide and strikes the reflector dish. In the arrangement shown in view A of figure 5-18, the microwave radiation flows from openings in the waveguide end located at the reflector focal point. The radiation is directed backward into the paraboloid.

Instead of the reflector being of glass (as is the mirror), or some other highly polished material, it is made of copper. It does not need to be solid, but may be of a meshed screen to reduce its weight and wind resistance.

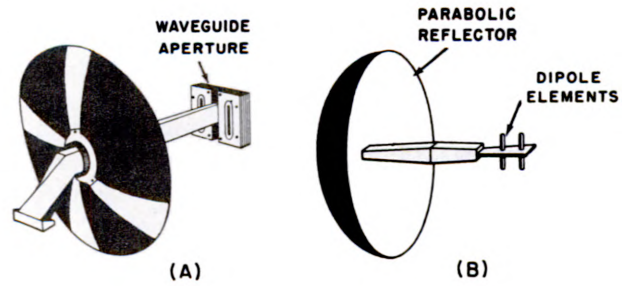

Figure 5-18.—Methods of feed.

TRUNCATED PARABOLOID: The truncated paraboloid has the same shape as the paraboloid with the top and the bottom of the paraboloid sliced off. With its long side placed horizontally, the beam is narrow in the horizontal plane and wide in the vertical plane (see fig. 5-19). This

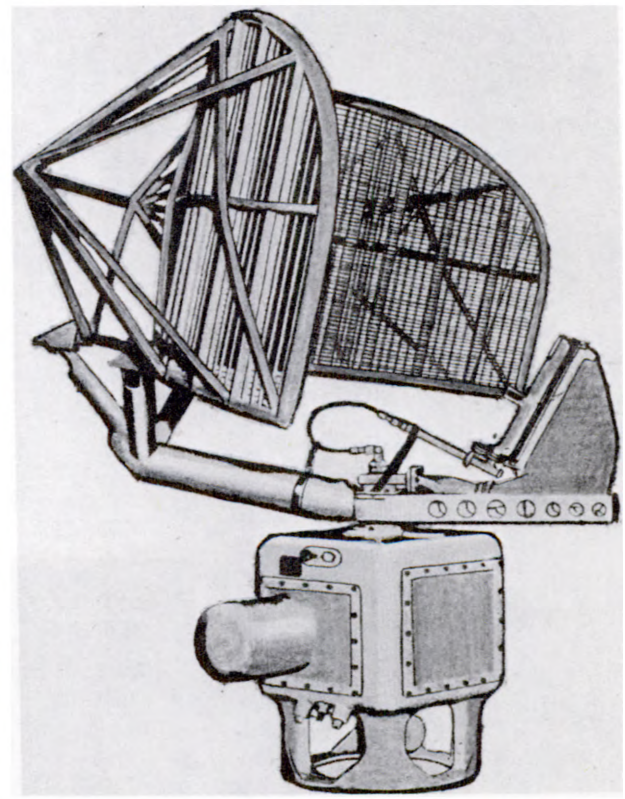

Figure 5-19.—AN/SPS-10, truncated paraboloid.

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is the most common type of antenna used by both air-search and surface-search radars.

Types of Scans

It is often desired to increase the horizontal or vertical coverage given by an antenna without increasing the beam width. To do this, various types of antenna scans are used. We will briefly discuss the conical, lobe switching, spiral scan, and vertical scan, which are some of the more common types with which you will be concerned.

1. A conical scan is accomplished by either rotating the radiating element of a paraboloidal antenna or by tilting the dish and causing a fixed point on its edge to rotate around the center. The resulting beam pattern is shown in figure 5-20.

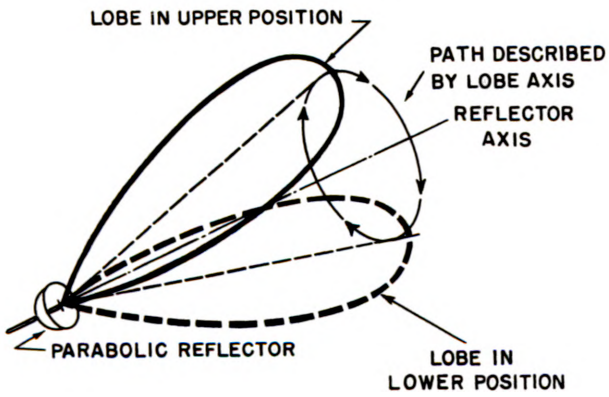

Figure 5-20.—Conical scanning.

2. With lobe switching, the radar beam is caused to move first in one direction and then in a different direction, producing a double lobe pattern as shown in figure 5-21.

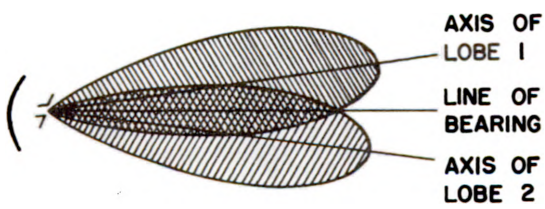

Figure 5-21.—Lobe switching.

3. A spiral scan is similar to the conical scan, the difference being that the amount of tilt given the dish is varied as the dish is rotated, resulting in a spiral pattern (fig. 5-22).

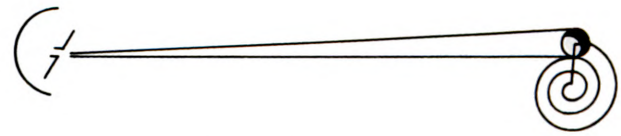

Figure 5-22.—Spiral scan antenna pattern.

4. In certain types of altitude-determining radars, a narrow beam of radiated energy from the radar antenna is scanned vertically through a given arc while the antenna is being rotated through 360° of azimuth. By displaying this information on a range-height indicator, position angle and altitude of the target may be determined. Position angle is the angle between the horizontal and the line of sight to the target (see fig. 5-23).

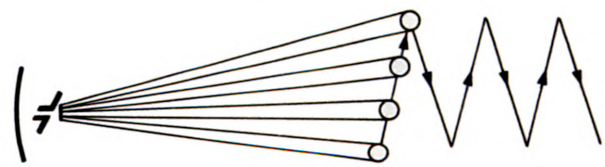

Figure 5-23.—Vertical scan.

Horn Radiators

Horn radiators are often used to obtain directive radiation of microwave energy and are frequently used as primary feed sources in radar antenna assemblies. The operation of an electromagnetic horn is similar to that of acoustic horns. However, the throat of an acoustic horn usually has an area much smaller than the sound wavelengths for which it is used, while the electromagnetic horn has an area comparable to the wavelength being radiated. Horn radiators are only sections of waveguides with open, flared ends. They act as terminations for transmission lines, especially waveguides. The horn can be considered as a type of transformer which matches the wave impedance of the waveguide to

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the wave impedance of free space. With the transmission line so terminated, there is little reflection of waves at the end and the energy flows into the surrounding space.

Horns may be constructed in a variety of shapes. Some of the basic types are shown in figure 5-24. They are useful in microwave applications since they not only match the impedance of the waveguide to external space but also produce directional wave patterns. The shape of the horn along the dimensions of the mouth, measured in terms of wavelength, determines the radiation pattern. In general, the larger the opening of the horn, the more directional is the resulting pattern for a given wavelength. An opening of about 5 wavelengths gives a radiated major lobe of about 30°.

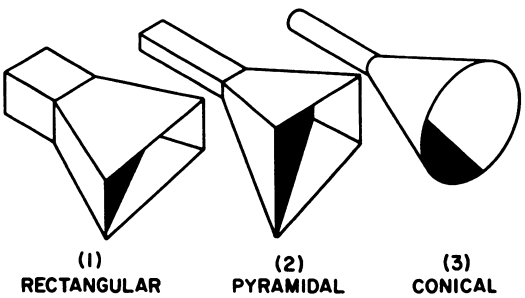

Figure 5-24.—Types of horn radiators.

DUPLEXER

Radar in its simplest form would require two antennas, one for the transmitter and another for the receiver. Such a system has several disadvantages. One of the more outstanding disadvantages is that many of the radars have large, bulky antennas. This is necessary to obtain good bearing accuracy. Hence, more space is required to mount these bulky antennas. Another disadvantage is that the receiving antenna would have to be thoroughly isolated from the transmitting antenna to prevent the high power of the transmitted pulse from feeding directly from the transmitting antenna back into the receiver. Even if the input stage were not permanently damaged, it would be overloaded to such an extent that the receiver would be blocked for several hundred microseconds or more; thus the receiver would be inoperative and would not amplify a pulse return from a nearby object.

In present-day radar it is desirable to use a single antenna for both transmitting and receiving. A fast-acting electronic switching device is required to disconnect the receiver from the transmission line during periods of transmission and to disconnect the magnetron during periods of reception. The receiver must be disconnected to protect the receiver input section and crystal since the magnetron output may be several megawatts. This function is performed by the T-R (transmit-receive) tube. The magnetron must be disconnected during periods of reception so that all available reflected energy will pass from the target to the receiver. This is accomplished by the A-T-R (anti-transmit-receive) tube.

The device used for this switching is known as a DUPLEXER. In performing this action the duplexer makes use of one or more T-R tubes.

The requirements for a radar duplexing device are as follows:

1. During transmission, the switch must connect the antenna to the transmitter and at the same time disconnect the antenna from the receiver. Also, the switch must isolate the receiver from the transmitter to protect the sensitive elements of the receiver.
2. In order to see close targets, the switch must rapidly disconnect the transmitter and connect the receiver to the antenna immediately after transmission.
3. During reception, the transmitter must be isolated from the incoming signal.
4. The switch must absorb little power.

There are many types of duplexers in use today, so no attempt will be made here to describe them all. However, it is important for you to know that the duplexer is a delicate instrument and one of the major tuning controls of a radar system. In most cases a technician should do the tuning.

Figure 5-25 illustrates the SG-6 duplexer at work. This duplexer connects the antenna to the transmitter for the time that the transmitter is on—1 microsecond. The antenna is then connected to the receiver until the time the transmitter is ready to be turned on again (about one six-hundred-fiftieth second).

TRANSMISSION LINES

Transmission lines may be described as any set of conductors used to carry signals or energy from one location to another. In radar systems, they are used to carry the energy from the transmitter (magnetron) to the antenna. Various types of transmission lines are used, depending upon the frequency of the radar, installation problems, etc.

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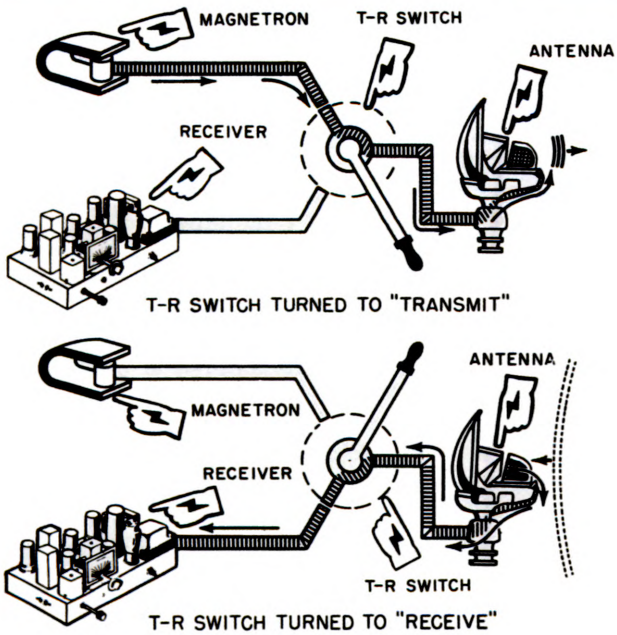

Figure 5-25.—Duplexer at work.

Open Line

An open line in its simplest form is nothing more than two wires, with a fixed spacing between them, that carry the energy. As higher frequencies are used, the losses become greater, resulting in various inefficiencies when used with frequencies above 500 MC.

Coaxial Cable

A coaxial cable (fig. 5-26), commonly abbreviated as "coax," consists of one conductor surrounded by another, the two being insulated from each other. It can be used at higher frequencies than an open line, but its efficiency decreases as frequency is increased. It is not considered efficient at frequencies in excess of 3000 MC.

Solid Coaxial

Concentric cables are also made with the inner conductor consisting of flexible wire insulated from the outer conductor by a solid and continuous insulating material. Flexibility may be gained if the outer conductor is made of a metal braid, but the losses in this type of line are relatively high. Some electronic countermeasures receivers and low-frequency air-search radars use this type.

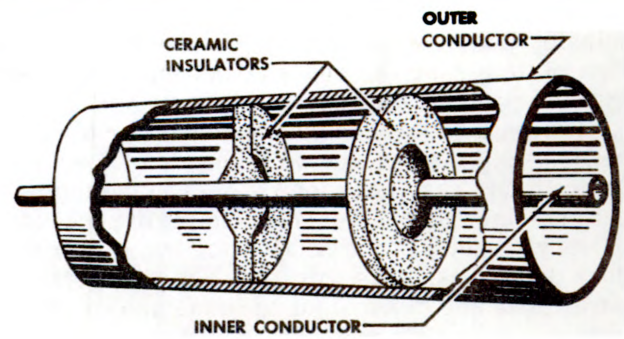

Figure 5-26.—Cross section of a coaxial cable.

Waveguide

A waveguide is essentially a hollow pipe which allows extremely high frequencies to be passed inside it with very little loss in power per unit length. It may be either round or rectangular. The size of the waveguide is determined by the frequency at which it will operate and also by the amount of power it can handle safely. In the case of the rectangular waveguide, the longer dimension determines the lowest frequency it will pass (frequency at which this dimension is half a wavelength long); and the shorter dimension is determined by its power-handling capabilities and the "polarization" of the transmitted energy (in the case of a feed horn radiator).

Figure 5-27 shows the structure of waveguides used with radar sets. It is not necessary to understand how these waveguides carry the wave motion through them. You are familiar with an ordinary speaking tube, in which the wave motion is not permitted to scatter, but is confined to a small area. By the reflection of the walls of the tube, the waves eventually reach the end and are sprayed out into the open.

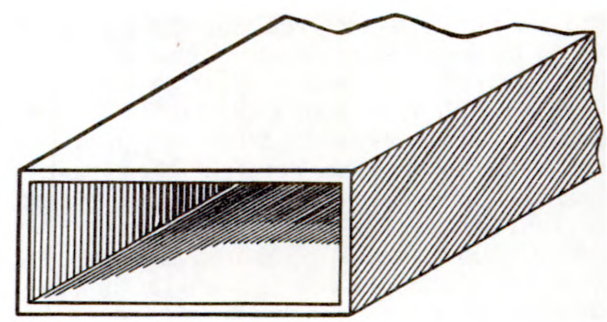

Figure 5-27.—Waveguide.

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POLARIZATION

The polarization of a radio wave is taken as the direction of the lines of force in its electric field. With a single-wire antenna, the direction of the lines of force in the electric field lies in the same plane as that of the antenna. In order to receive a radio wave efficiently, the receiving antenna must be oriented in the same plane as the polarization of the radio wave to be received.

Horizontal Polarization

An antenna's radiating element which is oriented horizontally with respect to the surface of the earth will produce a horizontally polarized wave.

Vertical Polarization

An antenna's radiating element which is oriented vertically with respect to the surface of the earth will produce a vertically polarized wave.

RECEIVER

The effective range of a radar system depends on its ability to distinguish between the echo returned by a target and other disturbances which may be present. Although the total radiated power may be many kilowatts, only a part reaches the target and a still smaller amount is returned to the receiving system. The available signal from the most distant targets may be about 1 microvolt or less. The receiver must be capable of amplifying this very weak echo signal, so that it can be used to control the electron beam of a cathode ray tube. Basically, the receiver is an amplifier in which vacuum tubes are used to increase the amplitude of a very small voltage.

The receiver in a radar system is actually a superheterodyne receiver such as the common home radio but a much finer one. The superheterodyne receiver is used almost universally because it provides a higher over-all gain with fewer tubes than other types of receivers. The heterodyne principle involves the changing of the higher carrier frequency to an intermediate frequency at which the gain per stage can be made greater. The frequency change is done by mixing, or beating, the received signal with a different frequency generated in the receiver. The mixer stage produces an output voltage which contains a frequency which is the difference of the two signals applied. The resulting signal is amplified by the intermediate-frequency (I-F) amplifier, and then is detected and amplified in the usual manner. Figure 5-28 shows a block diagram of a typical radar receiver. For any given local oscillator frequency there are two carrier frequencies which will produce the same intermediate frequency in the mixer output. It is desirable, therefore, to use a tuned R-F amplifier ahead of the mixer stage to discriminate against all but the desired carrier frequency.

The local oscillator generates a constant amplitude signal of 85 megacycles, which is mixed with the 100-megacycle input to produce a 15-megacycle intermediate frequency. The output of the mixer is amplified selectively to eliminate the 85- and 100-megacycle signal components which are present. In eliminating these components, the I-F amplifier must not distort the pulse shape of the received echo. When the pulse is applied to, or produced by, an R-F

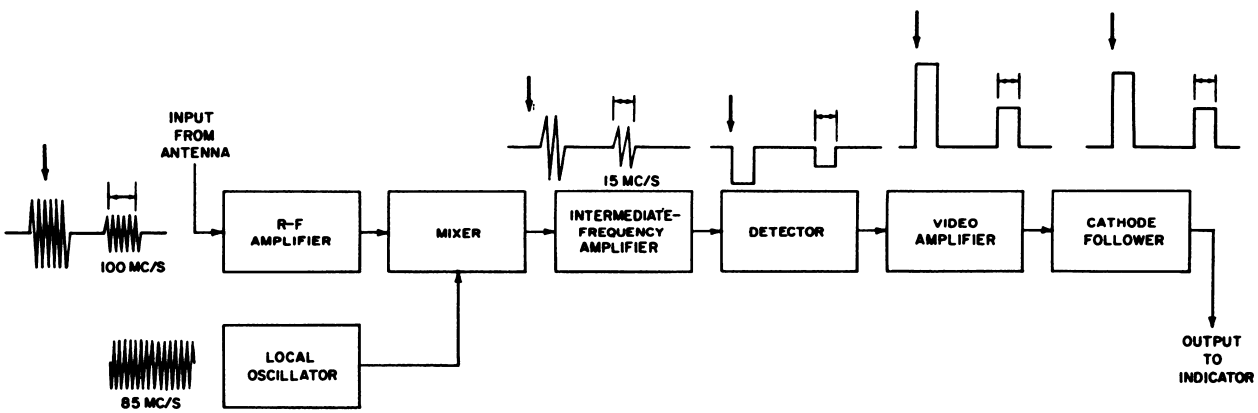

Figure 5-28.—Functional diagram of a superheterodyne radar receiver.

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generator, the transmitted energy consists of the carrier and side bands. These side bands extend both above and below the carrier frequency by an amount determined by the frequency components of the pulse itself. The bandwidth of the I-F amplifier must be great enough to pass the required side bands.

After the echo amplitude has been increased to a reasonable value, the signal is passed through a detector to reproduce the R-F envelope as a video pulse. The video amplifier provides the signal output necessary to operate the indicator, reproducing the pulse shape as faithfully as possible. Whenever a low-impedance load is to be placed across the terminals of the receiver, a cathode follower tube is used as a low-impedance output stage to match the load.

Many types of communication receivers and lower frequency radar receivers have one or more stages of amplification to "step up" the voltage of the R-F signal being received before the R-F signal is fed into the first detector or mixer. However, no practical means has yet been found to amplify microwave signals. As a result, receivers working in the microwave band do not have any R-F amplifiers. Instead they use a crystal mixer to generate the I-F rather than a vacuum tube mixer. The net effect of the crystal mixer is the same as a vacuum tube mixer. The R-F signal and the local oscillator signal are fed into the mixer, and out comes a signal at a much lower frequency (I-F) which can be easily amplified by the I-F amplifier. (The rest of the receiver action is the same.)

The radar receiver you will operate can be compared to an ordinary radio. To listen to a dance band from your favorite station, you must turn the knob on your radio to a spot on the dial where it will respond to the frequency of the desired broadcasting station. Your radar receiver likewise must be tuned to the frequency of the radar transmitter. Before you start to operate the gear, and occasionally during a watch, you must check the tuning of the radar receiver. On practically all modern radar receivers there is an automatic frequency control (AFC) that holds the receiver local oscillator 30 MC higher than the transmitter maggie frequency, thereby keeping the receiver signal at the I-F input centered on 30 MC. Also there is a manual tune control for adjusting the local oscillator to the correct frequency.

In addition to the knob used to tune your radio, you also have a knob that controls the volume of the voice or music. You don't get sound out of a radar, but you do get a sort of picture. Just as too much or too little volume is undesirable in a radio, so too large or too small a picture on the radar screen is undesirable. To control the volume of sound on your radio, you use the volume control. And to control the size of the image on the radar screen, you use the gain control. More about the use of the various controls found on the receiver will be covered in later chapters.

INDICATOR

The output of the radar receiver is connected to the radarscope through a video amplifier. So far, you know about two types of scopes used in connection with a radar system—the A-scope and PPI-scope.

The A-scope has its sweep repetition rate set at the same rate the transmitter blasts out its pulse of radio waves. In the example of a radar used throughout this chapter the repetition rate of the transmitter and the A-scope sweep is set to 650 pulses per second and 650 sweeps per second. In chapter 4 we discussed the forming of the sweep and range determination. When you really get down to it, the PPI is a range scope with a few revisions. Let's start with an ordinary A-scope and see what is necessary to convert it to a PPI.

Instead of having the echo deflect the sweep trace, you can arrange to have the echo brighten the sweep trace. You know that the brightness of the picture on the cathode ray screen can be changed by turning the intensity control either up or down. Varying the intensity control causes a change in the grid voltage of the cathode ray tube. When the grid becomes more positive with respect to the cathode, more electrons enter the cathode ray beam and the picture becomes brighter. When the grid becomes more negative with respect to the cathode, fewer electrons enter the cathode ray beam and the picture becomes dimmer.

The grid voltage on the cathode ray tube can be changed without touching the intensity control. The video amplifier signal voltages can be applied to the cathode ray tube grid to modulate the intensity of the beam. Television pictures are also formed by "intensity modulation" of the electron beam.

To have the radar echo signal brighten the sweep trace instead of deflecting it to cause a pip is a matter of disconnecting the receiver video amplifier from the vertical deflection plates and

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connecting the video amplifier output to the grid of the cathode ray tube. To increase the visibility of the bright spots, the general beam intensity is lowered so that the sweep trace is almost invisible. By doing this, the echo will appear as a very bright spot against a dark background.

To convert an A-scope into a PPI, use magnetic deflection instead of electrostatic deflection. Why this is necessary will be explained shortly. Remember, as stated in chapter 3, the A-scope's electron beam is moved by means of deflection plates. One pair of deflection plates is used to move the beam up and down, and another pair to move the electron beam from side to side.

A magnetic field can also be used to deflect the electron beam. However, instead of attracting or repelling the electron beam, a magnetic field pushes it to one side or the other.

Electromagnets are used for this purpose because the magnetic field they set up can be varied in strength by varying the amount of current flowing through the coil. Since there is no need for vertical deflection of the cathode ray beam, echo signals now cause the sweep trace to brighten. Only a single pair of electromagnets are required to cause a sweep trace.

Next, mount the sweep deflection electromagnets on a ring so that the electromagnets can be turned completely around the neck of the cathode ray tube. By changing the position of the sweep electromagnets, the sweep trace can be made to go from the center of the screen to any part of the rim (360°).

Finally, gear the sweep electromagnets directly to the radar antenna. The connection is made so that when the antenna turns, the sweep trace will rotate about the screen at the same rate.

When the antenna turns west, the sweep trace shows echoes being received from the west. When the antenna turns north, the sweep trace shows echoes being received from the north, etc. Your arm would get tired if you had to turn the antenna by hand continuously in order to scan 360°, so a motor is installed to do this for you. Different rotation speeds are available for different kinds of searches.

OPERATION OF A RADAR SYSTEM

You now have a complete and workable radar system, so let's go back over the operation, using only the A-scope.

To put the system into operation, turn on the transmitter for 1 microsecond. The pulse of radio waves travels from the magnetron up the waveguide, through the T-R switch, to the antenna, and out into space.

The instant the transmitter is turned on, the spot of light on the A-scope begins to move to the right. The transmitter pulse is so powerful that some of the radio waves leak through the T-R switch, travel down the receiver waveguide, are picked up by the receiver, and transferred to the scope. The transmitted pulse shows up on the range scope as a large voltage peak.

One microsecond after the transmitter is turned on, the transmitter is turned off, and the T-R switch is turned so that the antenna is directly connected to the receiver.

The spot of light on the A-scope screen continues to move to the right as the radio waves travel through space.

When the pulse of radio waves hits an object, the echo is reflected back toward the antenna.

From the antenna, the echo waves travel down the waveguide, reach the T-R switch, and are directed to the receiver. The receiver amplifies the echo and transmits the echo voltage to the range scope where it shows up at the proper range mark.

As soon as one six-hundred-fiftieth second has passed, the system is ready for the next transmitted pulse. The T-R switch has to switch over so that the transmitter is connected to the antenna and the scope sweep trace snaps back to zero miles. The system is now ready to transmit another pulse and receive the resulting echoes.

NEED FOR SPECIAL CIRCUITS

No human being could do efficiently what the radar system just described does automatically. One of the many reasons is that there are too many things to do and insufficient time in which to do them.

The transmitter must be turned on for 1 microsecond. You will find out that there are undesirable results if the transmitter is turned on for too long or too short a time. The longer the transmitter is on, the greater is the minimum range at which objects can be detected; the shorter time the transmitter is on, the narrower the echo signal on the scope screen. Just how long the transmitter should be left on is determined by the design purpose of the system—surface-search, air-search, or fire control. Obviously no man nor mechanical switch can turn the transmitter on for exactly the desired

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amount of time and turn it off every one six-hundred-fiftieth second; a special electronic circuit is required to do this job.

The directional antenna must be connected to the transmitter whenever the transmitter is on, and the same antenna must be connected to the receiver whenever the transmitter is off. This job of the T-R switch (duplexer) cannot be done by any person or any mechanical device—it must be done electronically.

Another important job that must be done is to start the scope sweep trace the exact instant the transmitter is turned on. This must be done every one six-hundred-fiftieth second. In this case also you can see that an electronic circuit is the only type of device that can do the job of synchronizing the scope sweep to the transmitter.

In addition to the jobs mentioned, there are dozens and dozens of other tasks that must be performed to make a radar system operate efficiently and almost completely automatically. Many kinds of special electronic circuits are required to perform all these special jobs. The maintenance of these special circuits is the responsibility of the ET's.

RADAR BAND DESIGNATION

Within the UHF and SHF bands the frequency ranges have been broken down into narrower bands of frequencies designated by letters such as P, S, L, X, and K. These bands have been further subdivided by the use of sub letters and/or numbers such as S_a, S_1, X_{b1}, X_c, and so forth. For example, say the S-band covers a total frequency range from 3000 MC to 4000 MC. Then 3000-3200 MC might be designated the S_a-band, 3200-3500 the S_b-band, and 3500-4000 MC the S_c-band.

In using these designations, the descriptive information of a radar equipment concerning frequency of operation would state "frequency range—S_a-band," rather than actually give the frequency in figures. The frequency ranges of each radar band are contained in other publications and will not be given here. In many instances the operating frequencies of certain equipments are classified and therefore should not be thoughtlessly discussed.

QUIZ

1. What is the relation between carrier frequency and the size of the radar antenna array for a given sharpness of pattern?
2. What determines the lowest pulse repetition frequency that can be used with a given radar antenna and indicator system?
3. What determines the minimum range at which a target can be detected?
4. What are the functions of the timer, or keyer, in a radar system?
5. What is the function of the transmitter in a radar system?
6. Why does a magnetron having high peak power run relatively cool?
7. Name five generating circuits that are applied to radar special circuits.
8. State a basic principle of the radiation of electromagnetic energy that pertains (a) to a moving electric field and its associated magnetic component; also (b) to a moving magnetic field and its associated electric field component.
9. Name the three parts of the antenna system.
10. What is the device that automatically connects first the transmitter and then the receiver to the antenna?
11. Why cannot the receiver and transmitter both be attached to the antenna at the same time?
12. Which type of transmission line is used with low-frequency or search radar?
13. What is done with radar antennas to cut off the back lobe?
14. What are minor lobes?
15. What type of receiver does radar employ?
16. Why do receivers working in the microwave band use a crystal mixer rather than a vacuum tube mixer to generate the I-F?
17. Where is the output of the receiver connected?
18. What happens when you turn the intensity control up on the cathode ray tube?
19. How else can the grid voltage be changed without touching the intensity control?
20. If the A-scope uses deflection plates to move the beam, what does the PPI use?

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CHAPTER 6

SURVEILLANCE RADARS

INTRODUCTION TO SHIPBOARD ELECTRONIC EQUIPMENT

The farmer, the truck driver, and the doctor all have to learn the capabilities and limitations of their tools. So also must the Radarman. This chapter is devoted to familiarizing you with some of the shipboard electronic equipment with which you will perform the tasks of collection, display, evaluation, dissemination, and control.

Equipment is described in the broadest terms possible and only to the extent necessary to enable the Radarman to realize its full capacities, and care for it intelligently while operating it.

Because there are so many models of radars in use in the fleet today, we will take one for an example, the AN/SPS-10, found aboard small as well as large ships, to point out the correct turn-on and turnoff procedures and tuning. The equipment will first be described in terms of its physical and electrical characteristics in order that you may better understand its capabilities and limitations, and the principles involved in making it work. Discussion of the operator's controls typical of any type of radar, their location, function, and use follow. Then you will be told how to start the equipment, and how to tune and adjust the controls. Later in the chapter, pointers will be given on electronic equipment operating techniques that would apply to any equipment.

Additional background material in this chapter is presented not with the hope of making a technician out of you, but to help you in dealing with the technicians who maintain this equipment.

LAYOUT OF EQUIPMENT

The following description applies to a large ship installation with several radars and many points of display. In smaller ships the layout will be simplified and in some cases will be less flexible than that described. This approach is necessary because, if the reader learns the more complex application, the simpler setup will be readily understood.

The large, modern warship has several radars. Each has been built with a specific purpose in mind but can perform other functions. A well-rounded installation has a surface-search radar, an air-search radar, and a height-finding radar, plus a great variety of fire control radars and in some cases, missile tracking radars. There are many stations, both within the CIC and elsewhere on board ship, that make use of the information provided by these radars. Any one of these stations may want the information from any one of the radars.

There must be a system for making available at each station suitable equipment for displaying a radar picture. This equipment is called a radar repeater, remote indicator, or simply a scope. There are many kinds of remote indicators, because the radar information is used for a number of different jobs.

We must have a way to transmit the radar information from each radar to these remote display points. Rather than run a cable with the necessary wires from each radar to every remote indicator, the cables are laid from each radar to a central distribution point from which cabling goes to each indicator. Suitable signaling and switching arrangements are provided so that the operator of a remote indicator can signal to the switchboard which radar input he wants at his indicator. The switchboard operator can supply the desired input simply by throwing the proper switch. Some switchboards are automatic. In addition to the video signals, the cabling in this system must carry the necessary synchronizing, azimuth positioning, and elevation position signals in order to place the video properly on the remote indicator.

Radars in themselves can only detect targets. They cannot tell the difference between friendly and unfriendly pips. For this reason, an auxiliary electronic system is tied to every search radar

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to distinguish between friend and foe. These systems are more commonly known as IFF (Identification Friend or Foe). The information produced by these systems will be fed to the same repeaters which the parent radar is connected to.

The radar, IFF, and display equipment described might be called the eyes of the ship. Communications, then, are the ears. The actual radio transmitters and receivers used in the fleet today are many and varied and are not dealt with in this text. However, the means within the CIC itself for controlling these communications, both within the ship and externally, are contained either in this text or in *Radarman* 3 & 2, Vol. 2. At each position in the CIC will be access to radio nets, sound-powered circuits, intercom systems, and intra-CIC systems. To eliminate confusion, control equipment has been built to keep all these communication systems straight. Figure 6-1 is a diagram of the relationship between radar, IFF, and repeaters.

Notice the IFF system at left half of illustration. It is actually a separate radar, but uses the same timer, power supply, and gyro as the radar system on the right. Combined signals from IFF and radar can be sent to repeaters for display.

The numbers in figure 6-1 do not stand for sequence. Instead, they represent the type of information passed from one element of the system to the other. No. (1) shows the paths of IFF information; No. (2), of radar information; No. (3), of timing information; No. (4), ships true course data; No. (5) power; No. (6), relative antenna bearing; No. (7), video control data; and No. (8), trigger and azimuth information. To read the diagram, simply determine the type of information you want to trace and follow the arrows.

NOMENCLATURE OF EQUIPMENT

The question arises as to whether the RD 3 is required to learn all the alphabetical and numerical designations of the equipment introduced. The answer is a qualified "yes". If a piece of equipment is labeled by its short title and a brief description, it is desirable that the reader be able to identify it.

To assist the trainee in learning the equipment discussed in this book, and other equipment he will meet in the fleet, a review of chapter 2 is recommended.

One source of confusion for the trainee is the habit of some personnel to drop the "AN/" from joint nomenclature designations. As an example, the AN/SPS-6C air-search radar frequently may be called the SPS-6C or the 6C.

SEARCH RADAR EQUIPMENTS

Radar equipment is capable of detecting the presence of an object in the air or on the surface, and of determining bearing and range. Some radar sets are capable of measuring directly the position angle of an air target, thus determining altitude. The maximum range and accuracies with which this information can be determined is established by the proper system constants for the radar equipment in question. No single radar equipment has been developed to perform all the combined functions of air-search, surface-search, altitude-determination, and fire control because of size, weight, power requirements, frequency band limitations, damage control problems, etc. As a result, individual radar equipments have been developed to perform each function separately. The system constants for each radar equipment are selected to enable it to fulfill its primary function in the best manner possible.

During the past 20 years the Navy has had many different models of search radars. No attempt will be made in this text to describe all the older models nor all the newer models.

Some of the older models are covered briefly since a few are still in use, and an acquaintance with their working principles will better help you understand newer models.

SURFACE-SEARCH RADARS

The primary function of surface-search radars is the detection and determination of accurate range and bearing of surface targets and low-flying aircraft while maintaining 360° search for all surface targets within line-of-sight distance of the radar antenna. The system constants of this radar will vary from those of the air-search radar. Since the maximum range requirement of a surface-search radar is primarily limited by the radar horizon, very high frequencies (X-band) are used to give maximum reflection from small target-reflecting areas, such as ship masthead structures and submarine periscopes. Narrow pulse widths permit short minimum ranges, a high degree of range resolution, and greater range accuracy. High pulse repetition rates are used for best illumination of targets. Medium peak powers can be used to detect small targets at line-of-sight distances.

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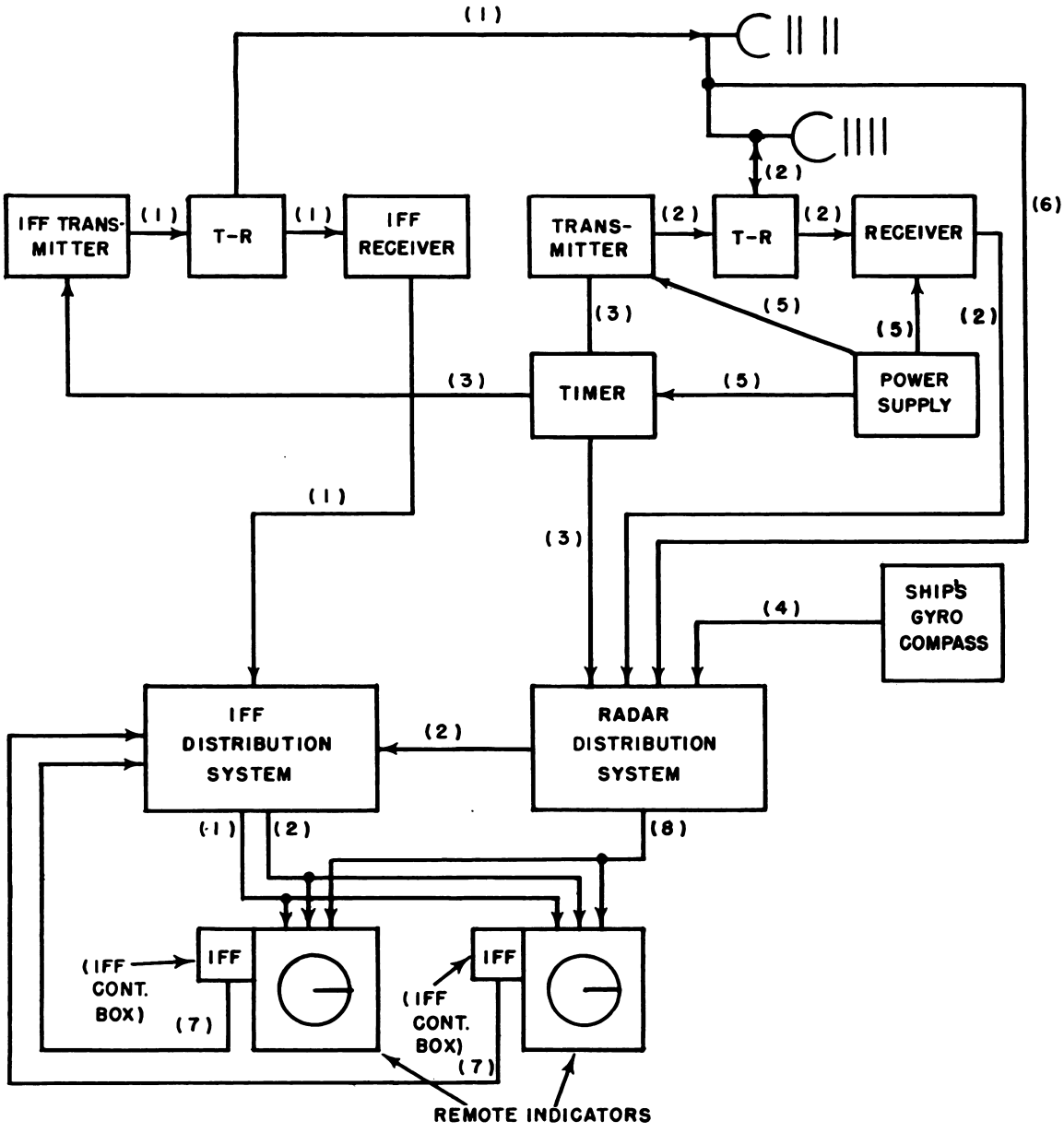

RELATIONSHIPS BETWEEN RADAR, IFF, AND REPEATERS

LEGEND

(1) IFF INFORMATION	(5) POWER
(2) RADAR INFORMATION	(6) ANTENNA BEARING (RELATIVE)
(3) TIMING INFORMATION	(7) VIDEO CONTROL
(4) SHIP'S TRUE COURSE	(8) TRIGGER & AZIMUTH INFO.

Figure 6-1.—Relationship between radar, IFF, and repeaters.

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Wide, vertical beam widths are used to compensate for pitch and roll of own ship and to detect low-flying aircraft. Narrow, horizontal beam widths permit accurate bearing determination and good bearing resolution. Following are descriptions of some of the older surface radar equipments of the Navy, and some of the present-day radars.

Model SG-1B

The original SG radar was installed on vessels larger than DD's in 1942. The SG-1B designation indicates that it is the original model SG with improvement modifications installed.

The SG-1B is an S-band radar with an R-F peak power output of 30 watts. It has two range scales, 15,000 and 75,000 yards, the latter being the maximum indicating range of its PPI-scope or A-scope. Pulse width is 2 microseconds, with a PRR selection of 800, 900, or 1000 CPS. Minimum usable range is 500 yards.

The parabolic antenna of this radar has a horizontal beam width of 5.3° and a vertical beam width of 15°. The antenna will rotate clockwise or counterclockwise, automatically, at speeds of 8, 16, or 24 RPM; or it can be rotated manually.

During the years the SG-series equipments were in active use by the Navy, it was considered a very good and stable equipment. Modern advancements have made it obsolete for several reasons, mainly because of its relatively low peak power.

Model SG-6B

The model SG-6B radar is a combined surface-search and zenith-search radar. Surface- and air-search radars have one area that neither cover—directly over the ship.

Special radars are designed for zenith-search coverage. To avoid adding another antenna to the already overloaded masts and superstructure sections of the ship, designers combined the surface-search and the zenith-search antennas, inasmuch as both are seldom needed at the same time. Thus was born the SG-6B radar, which combines the functions of a surface-search radar and a zenith-search radar. It should be understood, however, that both these searches cannot be performed at the same time.

The SG-6B is an X-band of 125 KW peak R-F power output. The PRR is variable from 625 to 650 pulses per second with two pulse widths available of either 0.37 or 1.3 microseconds duration as selected by the operator.

For zenith-search, a clamshell-shaped antenna is used. For surface-search, the antenna is a parabolic type. The two antennas are normally included in one unit and the equipment is shifted from surface to zenith, or vice versa, as desired.

The equipment has an A-scope indicator but its PPI indicator is normally a VJ remote repeater or an AN/SPA-4 series azimuth indicator.

AN/SPS-4

The AN/SPS-4 radar is a medium-power (180-285 KW peak power output) surface-search radar having a tunable magnetron, which may be operated at any frequency between 5450 and 5825 megacycles. The antenna permits the operator to observe targets on and near the surface of the water.

Targets are presented on the screens of a range indicator (A-scope) and a VJ-1 radar repeater, as well as on other repeaters, all of which may be connected.

The AN/SPS-4 radar is similar to the SG-6B, except for changes in the antenna, the transmitter, and the receiver to permit operation on the lower frequencies and at a higher power output.

Because of high-speed aircraft and the limited range capabilities of the zenith-search feature, a field change has eliminated it.

AN/SPS-21

This radar is a small, compact set to be used on small craft. It is lightweight and works in the X-band frequencies with a peak power of 8 KW. The pulse width is 0.2 microsecond with a PRR of 1500 PPS. It uses a parabolic-type reflector with a beam width in the horizontal plane of 2° and 15° in the vertical plane.

AN/SPS-35

Formerly known as the AN/SPN-21, this equipment is also used on small boats and is a short-range radar for surface search. The frequency is in the X-band and peak power is 7 KW. The pulse width is 0.2 microsecond, and the PRR is 1500 PPS. The radar beam is 2.2° in the horizontal plane and 14° to 18° in the vertical plane.

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AN/SPS-36

The AN/SPS-36 is another short-range, lightweight surface-search radar for use on small boats. It was formerly known as the AN/SPN-23. Peak power is 7 to 10 KW in the X-band frequencies. Pulse width is 0.1 to 1.5 and 0.45 microsecond with a repetition frequency of 1000 PPS. The horizontal beam width is 1.9° and vertical beam width is 25°.

AN/SPS-5

This system has been in the fleet for some time. It is small and compact enough to be used on DE's and smaller craft. It once had a tiltable antenna that could be elevated to detect aircraft at short ranges. It has been modified and now features a semifixed (nontiltable) antenna that is rotated 360° by motor. The horizontal beam width is 2.5° and vertical pattern is 15° coverage. A modification to the frequency band has also been made.

AN/SPS-10

The AN/SPS-10 is in service on a large number of ships. It is primarily a medium-range, high-definition, surface-search and limited air-search radar. The maximum range when detecting surface targets is normally greater than the optical horizon as received from the antenna reflector. (The optical horizon in miles equals 1.22 times the square root of the antenna reflector height in feet.) The strength of a received echo generally depends on the size and the shape of the target, its distance and altitude, the material of which it is made, and weather conditions. Since the AN/SPS-10 is a conventional surface-search and limited air-search radar, it cannot detect overhead targets.

The AN/SPS-10 operates in the frequency band from 5450 to 5825 MC with a peak power output of 200 KW. The magnetron is tunable over its frequency range. This feature is desirable so that the operating frequency can be changed to minimize interference from other radar sets operating at the same frequency.

Two pulse widths are available. The long pulse (1.3 microseconds) gives a longer range than the short pulse (0.25 microsecond). The PRR is variable with a range of 625 to 650 PPS.

The antenna is a horn-fed, truncated parabolic reflector with an average rotation speed of 16 RPM in a clockwise or counterclockwise direction. Beam width in the horizontal plane is about 1.5° and between 12° and 16° in the vertical plane. The bearing resolution, using short pulse, is less than 1°. Range resolution, using short pulse, is 41 yards; long pulse is 213 yards.

One of the qualifications for a Radarman Third or Second is to start, stop, and tune surveillance and height-finding radars to which assigned. Since there are many models of radar sets in use at the present time, a representative shipboard surface-search radar (the AN/SPS-10) is used in discussing the operating adjustments common to practically all radars. A general description of the major components is given, followed by a detailed discussion of some of the common operating controls and procedures. To be a good Radarman does not require that you be a technician, but you should be familiar with the location and general purpose of units that make up the equipment you will be operating.

Description And Function Of Units

Figure 6-2 illustrates the major units of Radar Set AN/SPS-10. You must keep in mind that, on your ship, these units will probably be scattered in various compartments. Make it a point to learn the location of the units on your ship.

FILTER, BAND SUPPRESSION, F-188/SPS-10 (sometimes called an R-F line filter): This filter serves to eliminate R-F leakage (conducted noise) from the primary power source to the radar set and from the radar set to the primary power source.

FILTER, BAND SUPPRESSION, F-189/SPS-10 (IFF filter): This filter is connected to the antenna assembly, and minimizes interference from the radar set to the IFF equipment used in conjunction with Radar Set AN/SPS-10.

VOLTAGE REGULATOR, TYPE CHS-3AAP-1: The voltage regulator maintains the regulated primary voltage at 115 volts A-C plus or minus 2 percent. It is equipped with a NON-REGULATING-REGULATOR ON selector switch so that the voltage regulator may be switched out of the radar system.

A voltmeter is provided for measuring the voltage output of the voltage regulator. A PRESS FOR LINE VOLTAGE pushbutton, when depressed, permits reading the line voltage without taking the voltage regulator out of the radar system, when the selector switch is in NON-REGULATING. With selector switch in REGULATOR-ON, meter gives constant indication.

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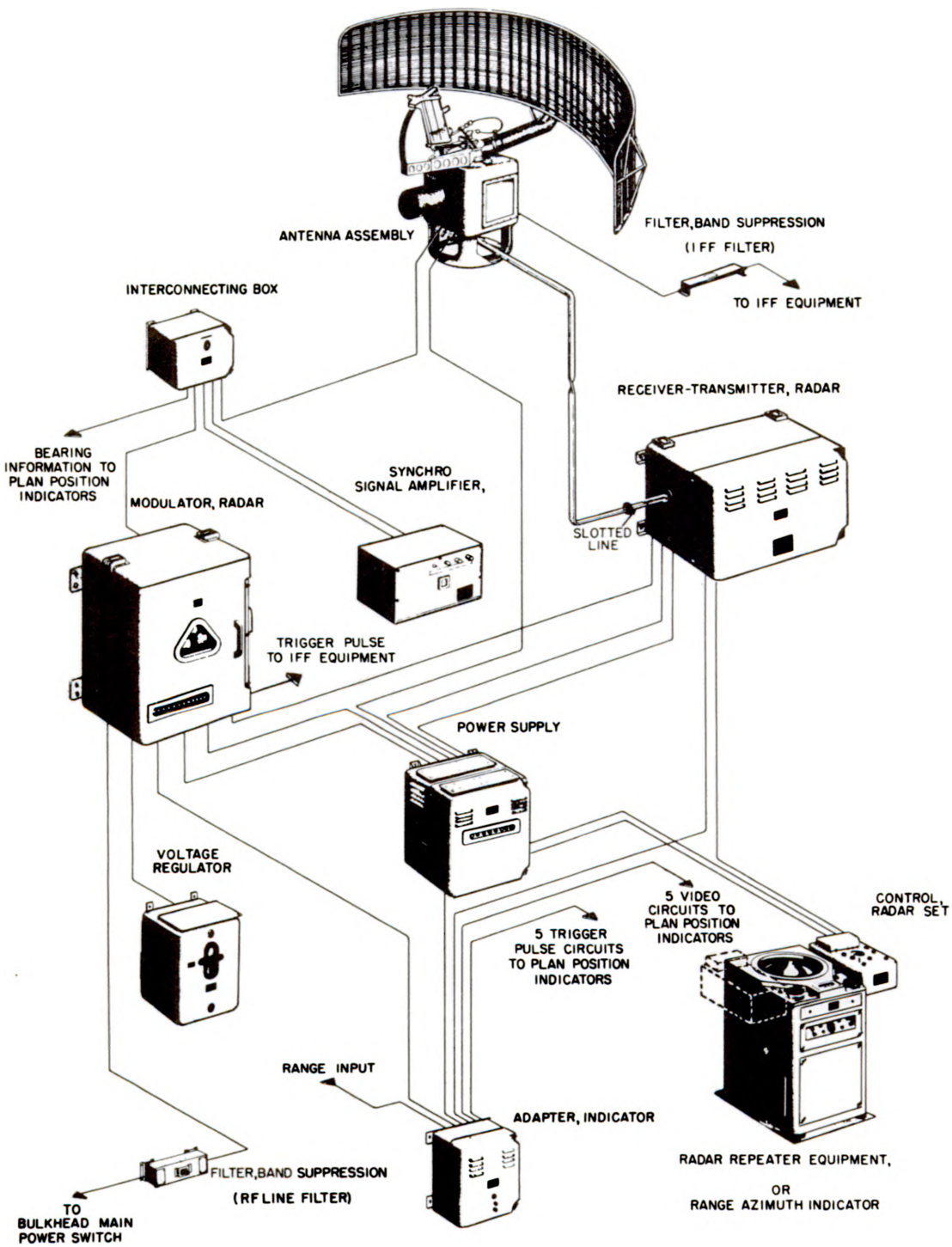

Figure 6-2.—Radar Set AN/SPS-10—relationship of units.

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This unit includes its own full-wave D-C power supply for an electronic sensing circuit which controls a motor-driven variable autotransformer connected to an intermediate booster transformer. The booster transformer will either add voltage to or subtract voltage from the voltage delivered by the ship's mains. As a result, a regulated voltage input is maintained to the various circuits of the radar set.

POWER SUPPLY PP-866/SPS-10: This unit provides four electronically regulated electron tube D-C power supplies for the receiver-transmitter. It also provides one unregulated (low-voltage) D-C power supply for the system control circuits.

When MAIN POWER switch on the radar set control is manually turned to the STDY (standby) position, a 3-minute time delay relay is energized. The delay prevents 115 volts A-C from being fed to the primary side of the power supply transformer of the unregulated power supply. This delay gives adequate time for certain tube filaments to heat sufficiently, thus preventing injury to these tubes when plate voltage is applied.

A blown fuse indicator shunts each fuse of the power supply unit to provide a visual check of its condition. In addition, a warning lamp on the fuse panel is visible when the unit is open and lights up when the power supply unit is energized. A thermal control switch provides a means of indicating overtemperature conditions by lighting an indicator light at the radar set control. You can get to a 115-volt A-C convenience outlet by opening the front cover of the unit.

MODULATOR, RADAR, MD-176/SPS-10: The modulator provides the modulating pulse for the transmitter, the synchronizing pulses for the other units of Radar Set AN/SPS-10, and, in addition, distributes 115-volt, 60-cycle power to the various units.

The modulator contains a trigger pulse generator chassis, a high-voltage switch chassis, a thyratron (keyer) tube chassis, and a rectifier tube chassis. The trigger pulse generator produces trigger pulse voltages of the proper waveform to fire the thyratron tube at a repetition rate of approximately 650 PPS during radar operation. This rate is adjustable from 625 to 650 PPS by means of a motor-driven capacitor which is remotely controlled by a pushbutton on the radar set control.

When the radar set is turned to beacon operation, a resistor-capacitor (RC) network in the high-voltage switch chassis provides a means for reducing the pulse repetition rate of the blocking oscillator in the trigger pulse chassis to half the frequency of the phase shift oscillator, or about 325 PPS.

A motor-driven, high-voltage, pulse-width switch selects one of three pulse widths (0.25-microsecond short pulse, 1.30-microsecond long pulse, or a 2.5-microsecond beacon pulse plus or minus 10%).

Low-amplitude samples of the modulating pulse, used to modulate the magnetron oscillator in the transmitter, are supplied to trigger and synchronize the indicator adapter. The modulating pulse and the trigger pulses are sent from the modulator through coaxial cables. These cables are connected to the jack assembly contained in the protective shield attached to the right side of the modulator cabinet.

A motor-driven blower and air cleaner (filter) provide ventilation for getting rid of heat generated by the modulator.

The power distribution circuit consists of an autotransformer, relays, a safety switch, and 11 fuses with blown fuse indicators.

Three meters are mounted on a hinged panel behind a viewing window in the front door of the unit. These are: (1) a time meter which shows directly the total number of hours during which the equipment is on; (2) a time meter which shows directly the number of hours during which the equipment is in the radiate condition; and (3) a milliammeter which measures relative magnetron average current for long-pulse, short-pulse, and beacon-pulse operation.

INTERCONNECTING BOX J-510/SPS-10: The interconnecting box serves (by means of its internally connected terminal boards) as a junction point for the modulator, synchro signal amplifier, antenna assembly, and radar repeater equipment (one master indicator and four remote repeaters).

The interconnecting box contains two capacitors for improving the power factor of the 1-speed and 36-speed synchros, a stepdown transformer which provides the proper voltage for the relative bearing warning light at the radar repeater equipment, and a selector switch for feeding either true or relative bearing information to the radar repeater equipment.

RECEIVER-TRANSMITTER, RADAR, RT-272/SPS-10: The receiver and transmitter are housed together in one cabinet.

The receiver portion of this unit is mounted on a specially shielded, readily accessible,

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hinged panel inside the front cover. A hinged auxiliary control panel for local control is located above the receiver panel.

The transmitter, with its associated equipment, is mounted in the receiver-transmitter cabinet behind the receiver panel and auxiliary control panel.

The receiver uses two local oscillators, one for radar operation and the other for beacon operation. By means of a selector switch on the radar set control, the receiver may be placed in either radar or beacon operation. The receiver contains broad-band I-F strip video stages, IAGC (instantaneous automatic gain control) circuits for reducing interference from strong returned signals, an FTC (fast time constant) circuit which can be used with or without IAGC to distinguish land-masked targets, an STC (sensitivity time control) circuit which reduces receiver gain for signals from targets at short range and yet maintains full gain for signals from targets at greater range, and separate AFC (automatic frequency control) circuits, one for radar and one for beacon operation.

The transmitter consists of a high-voltage pulse transformer, a magnetron oscillator, a duplexing system which includes a TR tube for protecting the receiver from excessive input during the transmission period, two ATR tubes to prevent a loss of received energy in the magnetron, a mixer, an echo box, a blower to provide a means of cooling, and other equipment such as the probe for the slotted line, interlocks, and fuses. An opening in the upper left side of the receiver-transmitter permits the slotted line or waveguide transmission line to be bolted directly to a waveguide flange on the duplexer.

An echo box (resonance chamber), located in the receiver-transmitter, can be tuned either by means of a pushbutton on the radar set control which operates the control motor of the echo box, or by means of a manual tuning knob attached to the shaft of the echo box motor.

The echo box constitutes a high Q (quality or figure of merit) tuned circuit at the transmitter frequency whose energy storage properties are used to provide an artificial echo on the plan position indicator. This artificial echo gives an indication of the over-all performance of the radar set.

The auxiliary control panel contains the following equipment and controls: an ECHO BOX TUNE knob, a LOCAL-REMOTE switch, an STC (ON-OFF) switch, an RDR BCN-AFC (ON-OFF) switch, an OFF-RADIATE-START switch, and a milliammeter and selector switch for measuring beacon AFC crystal current, radar AFC crystal current, magnetron current, receiver crystal current, and video detector current. It also includes seven manual controls, located near the bottom of the panel, that have the following adjustments: receiver tuning, beacon tuning, receiver gain, video detector zero set, STC duration, STC magnitude, and STC flat control.

SLOTTED LINE IM-82/UP: The slotted line (also called slotted waveguide) is a section of rectangular waveguide which bolts to the flange of the duplexer located in the upper left side of the receiver-transmitter.

This unit provides a means for making standing-wave measurements. (Standing-wave measurements are discussed later in this chapter.) The top surface of the slotted line has a slot cut through it and is provided with a sliding cover. The slot should be covered when measurements are not being taken. An R-F probe, normally stored on the inside of the door of the receiver-transmitter, is connected to an amplifier and a meter and is inserted into the slot to make the measurements.

ANTENNA ASSEMBLY AS-615/SPS-10: The antenna assembly includes a truncated parabolic reflector, feedhorn, IFF dipole, IFF load-matching section, IFF corner reflectors, and gear with driving mechanism. The radar horizontal beam width is about 1.5°, whereas the IFF horizontal beam width is about 6°.

The gear box contains a drive motor and gear train, one 5G synchro, one 5HG synchro, an oil pump to circulate oil to the antenna shaft bearings, a thermally controlled heater to prevent the oil temperature from dropping below 25°C (77°F), a pair of cam-actuated microswitches to operate the ship's heading marker circuit, two convenience outlets, and a manually operated disabling switch located on the outside of the gear box.

ADAPTER, INDICATOR, MX-1399/SPS-10: The indicator adapter contains its own power supply, a ship's heading marker circuit, a video amplifier circuit, a trigger pulse delay circuit, and video mixer circuit for range marks.

The video amplifier stages provide enough video power amplification of the echo video pulses to give five identical low-impedance outputs. These outputs may be distributed individually to five standard Navy plan position indicators.

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The trigger pulse delay circuit has an adjustable compensating time delay between the transmitted microwave pulse and the trigger pulse generated by the modulator. The trigger pulse time delay is accomplished by the combination of several low-pass filter networks. Forty-eight sections provide a total time delay of 2.4 microseconds in steps of 0.05 microsecond each.

The delayed trigger pulse is amplified and fed to five cathode followers which supply five identical synchronizing trigger pulses for triggering indicator repeaters.

An amplifier and a multivibrator circuit furnish the ship's heading marker signals for mixing with the video signals. Provisions are also made for mixing a positive 5-volt range marker signal with the video signal.

The power supply provides both plate and bias voltages for the unit. The unit has a fuse and a blown fuse indicator for its 115-volt, 60-cycle input supply.

CONTROL, RADAR SET, C-1134/SPS-10: The radar set control, called the general control unit on many radars, contains all necessary controls for operating the radar system.

The infrequently used controls are located near the top of the front panel behind a hinged cover. These controls are: STC magnitude, STC duration, STC flat, antijam selector switch, pulse repetition rate (PRR) control switch, and a ship's heading marker (SHM) ON-OFF switch.

The normal operating controls mounted openly on the front panel are: an echo box switch (button); three overtemperature indicating lights (modulator, receiver-transmitter (RT), and power supply (PS); a D-C monitoring meter with selector switch for measuring receiver crystal current, radar and beacon AFC crystal current, magnetron current; a main power switch; a pulse-width selector switch (BCN radar); an AFC (ON-OFF) switch; an antenna (CCW-OFF-CW) switch; an STC (ON-OFF) switch; and adjustments for receiver gain and receiver tuning. The control identifications are illuminated for dark space adaptation; a dimmer controls the intensity of the illumination.

The radar set control can be mounted on either side of the indicator of Radar Repeater Equipment, Navy Model VJ-1 or Range Azimuth Indicator AN/SPA-4A.

ACCESSORY EQUIPMENT: A standard Navy plan position indicator (Radar Repeater Equipment, Navy Model VJ-1) and a Synchro Signal Amplifier Mk 2 Mod 2A may be used with the radar set. Instructions on how to operate them will have to be obtained from the instruction book that applies to each.

The AN/SPA-4A is a radar repeater that is replacing most VJ's, and is suitable as a master indicator or a remote indicator. It is designed for use with any type of naval search radar capable of presenting range and bearing information.

System Function

The over-all operation of Radar Set AN/SPS-10 can be traced on the functional block diagram, figure 6-3. Main system flow is illustrated by heavy lines and supplementary circuits by light lines.

Radar Set AN/SPS-10 is designed to operate from a primary power source of 115 volts plus or minus 10 percent, 60 cycles, single phase, 90 percent power factor. It requires about 3.5 KVA. Primary power for system distribution is fed to the modulator through a line filter. This filter serves to eliminate R-F leakage (conducted noise) from the primary power source to the radar set and from the radar set to the primary power source.

Primary power is delivered to the modulator and divided into regulated and nonregulated sources for distribution to the radar set. An electronically controlled voltage regulator maintains the regulated primary voltages at 115 volts A-C plus or minus 2 percent. A power supply provides the necessary unregulated and regulated D-C voltages required for proper operation of the various circuits.

In the modulator the 115 volts A-C is stepped up to a high voltage by a transformer and rectified by a full wave rectifier. This high potential is filtered by a capacitor input filter, fed through a resonant charging choke and a charging diode to one of three pulse-forming networks (a long-pulse network, a short-pulse network, or a beacon-pulse network). Any one pulse-forming network may be selected by a motor-actuated high-voltage switch.

A thyratron keyer tube, together with one of the selected pulse-forming networks, converts the high potential D-C voltage into negative rectangular high-voltage pulses. The length of the pulses is sufficient to compensate for the delay in starting the transmitter. The transmitter then develops R-F pulses having the following lengths: 0.25 (WSP), 1.30 (WLP), or 2.25 (beacon) microseconds, depending on the pulse-forming network selected. The pulse repetition rate is determined by an RC coupled phase shift

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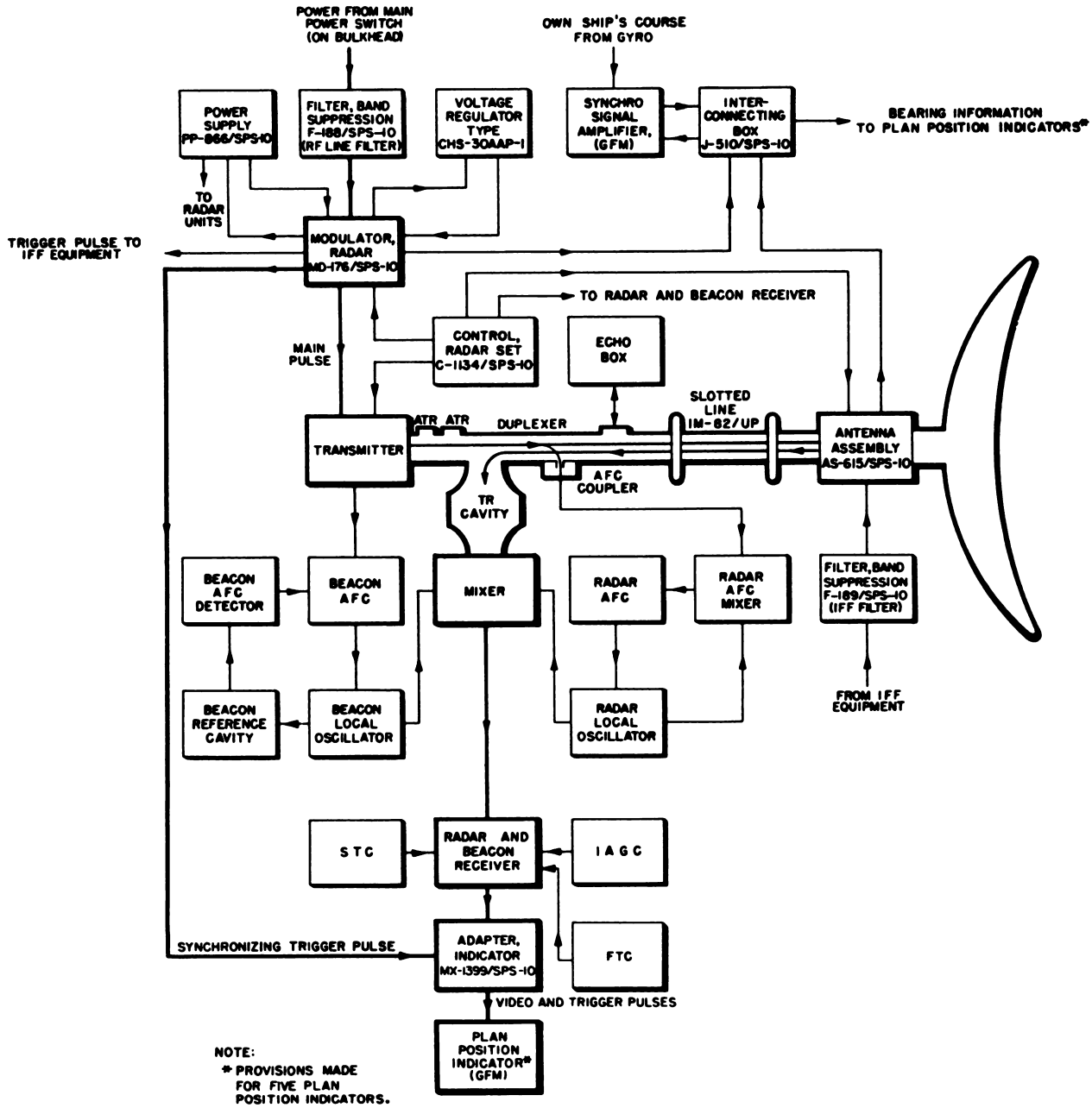

Figure 6-3.—Radar Set AN/SPS-10—functional block diagram.

oscillator whose frequency is variable from 625 to 650 PPS. Within these limits (625 to 650 PPS), the repetition rate is adjustable by means of a pushbutton switch that permits the capacitance of the RC network to be varied. The pulse repetition rate for beacon operation is one-half the radar repetition rate.

These negative pulses (main pulses) generated in the modulator are conducted to a pulse transformer in the transmitter, where the amplitude is increased from 5 KV to approximately 20 KV. The pulses pass through the pulse transformer to a magnetron oscillator with no change in polarity or waveform. Application of the pulses

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to the magnetron places the magnetron in operation and causes it to generate microwave energy for a time interval equal to the length of each pulse.

The modulator also provides low-amplitude samples of the main pulses. These low-amplitude pulses indirectly trigger the plan position indicators and synchronizing circuits of external and auxiliary equipments which may operate in conjunction with the radar set.

The microwave output energy of the magnetron oscillator is conducted to the antenna assembly through a duplexer, slotted line, and rectangular waveguide. This energy is then directed by a feedhorn (hoghorn type) to the surface of a slatted parabolic reflector. The antenna reflector concentrates and radiates the energy into space. The pattern permits the radar set to receive returned signals from aircraft targets that otherwise might not be detected. As the antenna reflector rotates (16 RPM), the beam sweeps over the surrounding area to search for both surface and aircraft targets within the limits of the height of the antenna reflector and the range limits of the radar set.

When the radiated energy strikes a target, a small portion of this energy returns to the antenna reflector. The reflector conducts this reflected energy to the receiver through the waveguide, slotted line, duplexer, and TR cavity. The TR cavity acts as an automatic electronic shorting switch, unblocking the receiver to the waveguide while the transmitter is not radiating and blocking the receiver from high-energy pulses of the transmitter while radiating. Two ATR tubes, located near the magnetron oscillator, present a high impedance to the returned signal energy, thus preventing loss of the returned signal at the magnetron oscillator during the receiving interval.

The received signal is directed through the TR cavity to a mixer. In the mixer the returned signal frequency is mixed with the frequency of the radar or beacon local oscillator. The radar local oscillator operates at a frequency 30 MC higher than the returned signal frequency. The beacon local oscillator operates at 5420 MC (30 MC below the received beacon signal). The difference frequency component of the mixer output (intermediate frequency) is selected and amplified by the I-F amplifier in the receiver.

Both the radar local oscillator and beacon local oscillator are coupled to the receiver mixer. This method of coupling permits the use of a common I-F amplifier for either beacon or radar reception. Either the beacon or radar oscillator is turned on independently for the desired type of operation.

After eight stages of I-F amplification, the signal is converted to video pulses which are fed through a video limiter and amplifier. The amplified video signal from the receiver is then delivered to the indicator adapter. After two more stages of video amplification, the signal is fed to five cathode followers. These cathode followers couple the video signal to plan position indicators.

Automatic frequency control (AFC) circuits are provided for the radar and beacon local oscillators. Radar AFC maintains a constant intermediate frequency of the receiver, regardless of minor drifts in transmitter frequency. The radar AFC circuit, incorporating a 30-MC amplifier and discriminator, compares the magnetron frequency with the radar local oscillator frequency. It thereby provides a voltage to correct the radar local oscillator frequency for the proper intermediate frequency.

The beacon AFC circuit serves to maintain the proper local oscillator frequency during beacon operation. It utilizes a beacon reference cavity pulse which is pretuned to 5420 MC.

The sensitivity time control (STC) circuit reduces the gain of the receiver the instant the transmitter pulses. The gain is reduced for a short period of the sweep time and then rises gradually to normal. The STC circuit is of value in reducing sea-return at close ranges so that nearby targets can be made out. It does not affect the presentation on the PPI of targets which are beyond the STC range. The time interval needed to restore fully the receiver gain limits the range and determines the maximum effective STC range.

The fast time constant (FTC) circuit makes it possible to see more clearly individual targets in a cluttered area which otherwise would appear as a large mass on the PPI. This feature is useful when many strong close-in targets exist. The blotting out of nearby target areas on the PPI is thus greatly reduced.

The instantaneous automatic gain control (IAGC) circuit prevents intense signals from overloading the I-F amplifier. The IAGC circuit reduces the gain of the I-F amplifier for the duration of the received signal.

The video signal that is delivered to the PPI is again amplified and applied to the signal grid of the cathode ray tube in the PPI, causing intensity modulation of its electron beam. The

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target signal is thus converted into visible intelligence on the screen of the PPI where it appears as a bright spot.

Circuits are provided so that the range and bearing of the target can be determined at the PPI. A synchro signal amplifier, which is connected to the radar set through the interconnecting box, delivers true bearing (own ship's course) information to the PPI. A TRUE-RELATIVE bearing switch in the interconnecting box connects either true or relative bearing information to the PPI.

An IFF coaxial filter, connected to the antenna assembly, lessens interference from the radar set to the IFF equipment used in conjunction with Radar Set AN/SPS-10.

OPERATION OF THE AN/SPS-10

Safety features have been installed on the radar set for protection of operating personnel and the radar set itself. However, it is absolutely necessary that the operator practice all safety precautions whenever he uses the set or makes adjustments.

You should thoroughly familiarize yourself with the operation of this equipment, concentrating on the function and location of all operating controls. Learn the procedure on the instruction plaque that you will find located near the radar set control.

Be sure to follow the operating procedures for equipment accessory to the AN/SPS-10 outlined in the instruction books for the standard Navy plan position indicator—the AN/SPA-4A or the VJ-1.

Remember: Quick, accurate, and decisive determination of range, bearing, and type of targets can only be achieved through concentrated effort by you, the operator.

Basic Principles of Operation

The radar set transmits electromagnetic microwave pulses and receives the returned echo signals. The range of a target is determined by measuring the elapsed time interval between the transmission of a pulse and the reception of its echo signal. Azimuth bearing information (relative or true) is determined by the angular position of the antenna reflector with respect to own ship's heading or true north.

Beacon operation of the radar set provides an electronic navigational system. The radar set generates and transmits electromagnetic microwave pulses which activate strategically located navigational aid pulses. These pulses are received by the radar set and are used as navigational data. The same receiver is used for both radar and beacon operation.

Prechecks

WARNING—High voltage is used in the operation of this equipment. Death on contact may result if personnel fail to observe safety precautions.

1. MAIN POWER: Before the equipment is placed in operation and the main power switch on the bulkhead (which controls primary power to the radar set) is turned on, all safety interlocks must be closed. The battle short switch in the modulator and the main power switch on the radar set control (fig. 6-4) should be placed in the OFF position. The drive motor disabling switch on the antenna assembly must be in the ON position.
2. ANTENNA OIL HEATER: A thermostatically controlled heater is provided in the oil compartment of the antenna gear box. It prevents the lubricant from thickening in cold weather. The oil heater can be

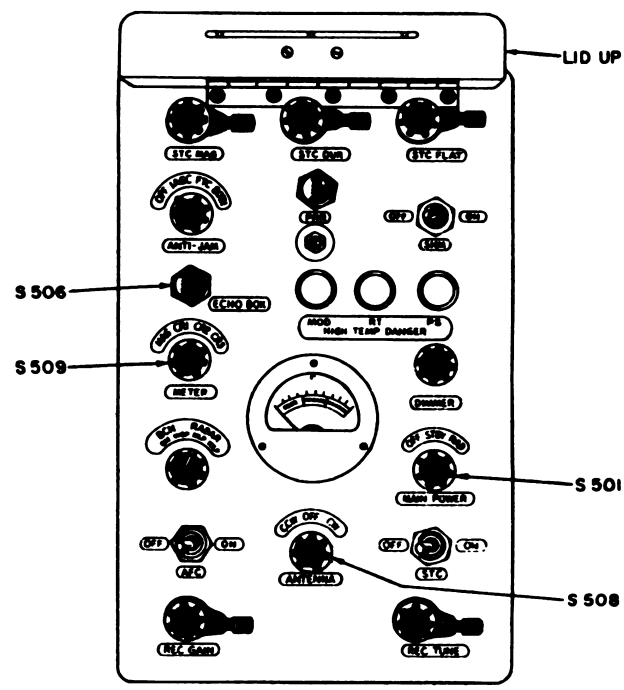

Figure 6-4.—Radar set control—front panel controls.

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turned off only by turning off the main power switch to the radar set (on bulkhead).

3. BLOWERS: A blower is provided in the modulator and in the receiver-transmitter to circulate air during periods of operation. The two blowers are immediately energized when the main power switch, located on the radar set control, is in either standby or radiate position. Additional protection for magnetron cooling is provided by an air flow switch. Failure of the blower in the receiver-transmitter closes the air flow switch causing the HIGH TEMP DANGER (RT) indicator light to glow.
4. LOCAL-REMOTE AND OFF-RADIATE-START SWITCHES (auxiliary control panel): During normal operation of the radar set control, make certain that the local-remote switch is on REMOTE and the off-radiate-start switch is on RADIATE.
5. EMERGENCY STOP: To turn off the equipment in an emergency, the following methods can be used:
   a. Turn main power switch on the radar set control to the OFF position.
   b. Turn main power switch to the radar set (on bulkhead) to the OFF position.

CAUTION.—If the main power switch to the radar set (on bulkhead) is used to turn off the equipment in an emergency during cold weather, it should be turned back on without delay because damage may occur to the antenna gear box due to thickening of lubricant.

Operational Checks

Regularly make the following checks to prevent damage to the radar set by improper operation.

1. Check the overtemperature indicators (table 6-1) on the radar set control (fig. 6-4). If any of these indicators glow, turn off the radar set and notify the technician. In an emergency, operation may continue for a limited time.

Table 6-1. — Overtemperature Indicators.

Designation	Location	Color of light
PS	Radar set control	Red
RT	Radar set control	Red
MOD	Radar set control	Red

2. Check the magnetron current on the transmitter current meter located in the modulator (fig. 6-5). It should read in the NORMAL portion of the meter scale. If the meter reads in the DANGER portion of the scale, the equipment must be shut off immediately and the technician notified. In an emergency, operation may continue for a brief time.

Starting the Equipment

The following procedures must be followed, otherwise damage may occur to the set.

1. Check that the main power switch to the radar set (on bulkhead) is ON. This switch must remain on at all times.
2. Check that the following control switches are in the indicated positions:
   a. MAIN POWER switch on the radar set control at OFF.
   b. BATTLE SHORT switch on the modulator at OFF.
   c. NONREGULATING-REGULATOR ON switch on the voltage regulator at NONREGULATING.
3. Check that the following control switches on the auxiliary control panel of the receiver-transmitter are in the indicated position (fig. 6-6):
   a. OFF - RADIATE - START switch at RADIATE.
   b. LOCAL-REMOTE switch at REMOTE.
4. Turn the main power switch on the radar set control to STBY. Adjust the intensity of the panel illumination to the desired brilliance using the dimmer control.
5. Turn on the plan position indicator and synchro signal amplifier. Refer to their instruction books, if necessary.
6. At the voltage regulator depress the PRESS FOR LINE VOLTAGE switch and read the line voltage on the meter. The line voltage should be 115 plus or minus 10 percent (103.5 volts A-C to 126.5 volts A-C). If the line voltage is outside this operating range, deenergize the radar set and notify the technician.

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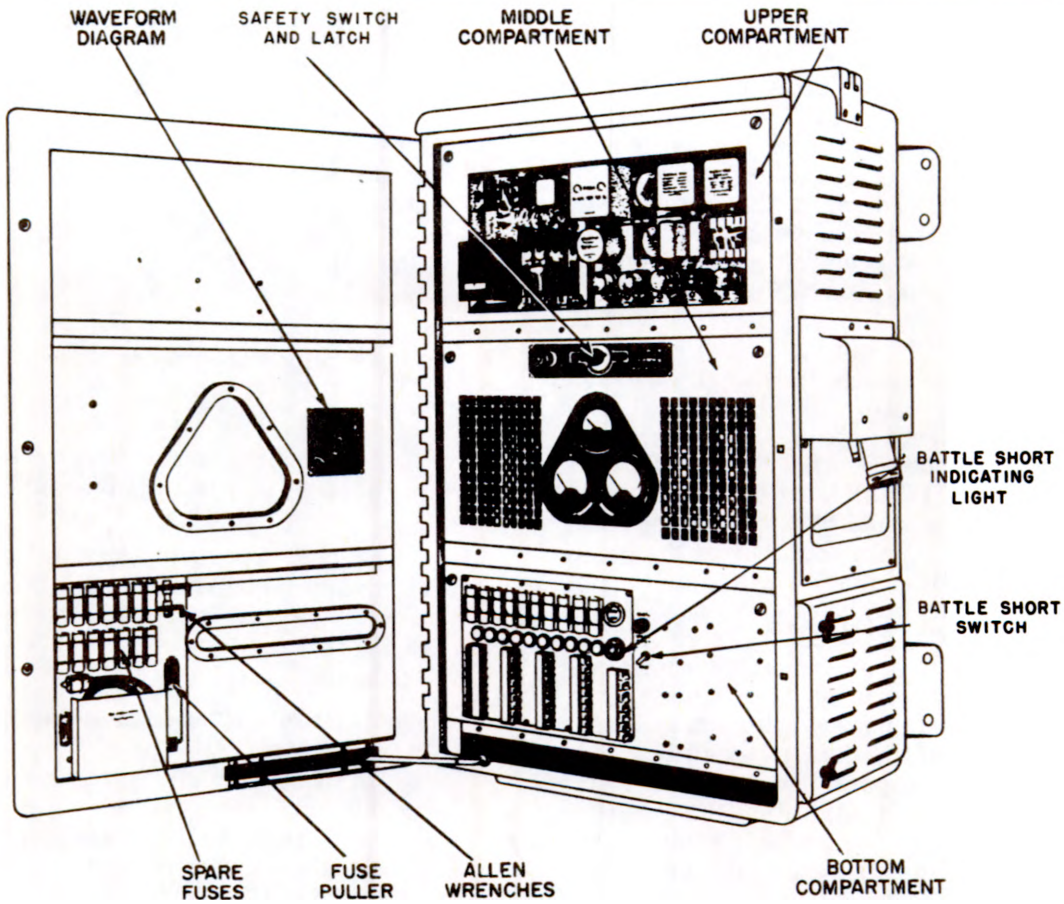

Figure 6-5.—Radar modulator—front panel controls.

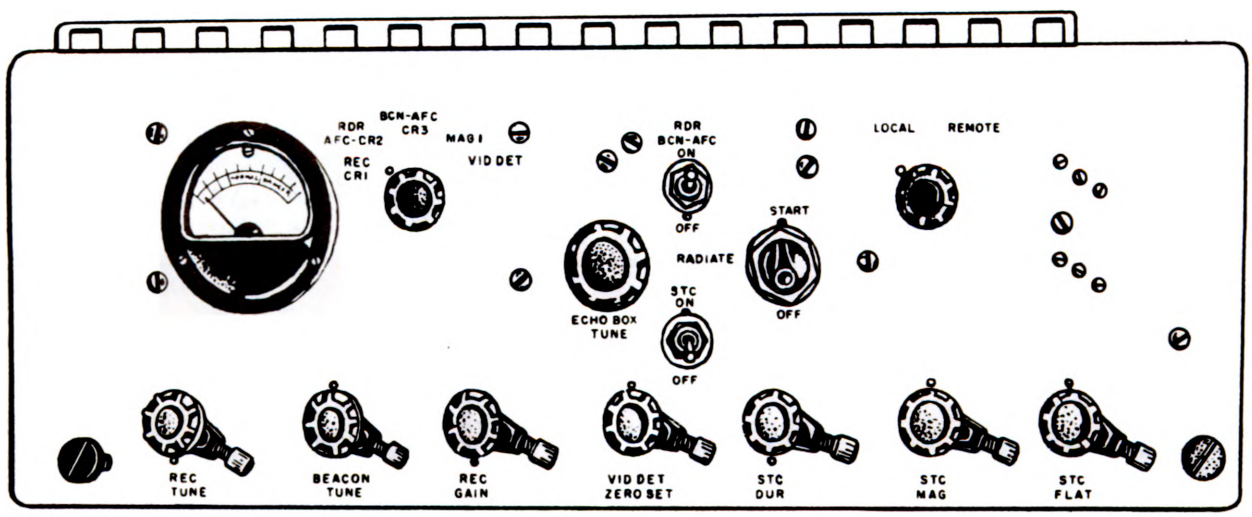

Figure 6-6.—AN/SPS-10 receiver-transmitter—auxiliary control panel, front panel controls.

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7. Turn the NONREGULATING-REGULATOR ON switch on the voltage regulator to the REGULATOR ON position.
8. At the voltage regulator, read the regulator output voltage on the meter. The regulated voltage should be 115 plus or minus 2 volts. (The meter reads the regulated output voltage when the PRESS FOR LINE VOLTAGE switch is NOT depressed.

CAUTION.—If the regulated voltage is not within the specified range, turn NONREGULATING-REGULATOR ON switch to the NONREGULATING position and notify the technician.

9. Turn the ANTENNA switch at the radar set control to the desired position (CW or CCW).
10. Turn the TRUE-RELATIVE bearing switch on the interconnecting box to the desired position (TRUE or RELATIVE).
11. Three minutes after switching to STBY, turn the main power switch to RAD.
12. Turn the BCN-RADAR selector switch at the radar set control to the desired position. See table 6-2.

Table 6-2. — Radar Selector Switch Positions.

Position	Purpose and pulse types
WSP	Wide receiver bandwidth, short pulse, least range, high definition.
WLP	Wide receiver bandwidth, long pulse, medium range, good definition.
NLP	Narrow receiver bandwidth, long pulse, longest range, least definition.
ON	Beacon operation.

13. Check that the following control switches on the radar set control are in the indicated positions:
    a. AFC switch at ON.
    b. STC switch at OFF.
    c. ANTI-JAM switch at OFF.
14. Adjust the REC GAIN control on the radar set control and the appropriate controls on the plan position indicator to obtain the desired presentation.
15. Special operating features STC, IAGC and FTC can be energized at the radar set control. These controls should not be used except for the conditions described in the last chapter. You must remember that other stations are using the same radar for other purposes, such as the officer of the deck, for example, to keep the ship on station while in formations. If you play with these controls, you might endanger the ship.

Tuning Adjustments

1. Receiver tuning (radar set control):
    a. Place the radar set in normal operation.
    b. Check that the following controls are in the indicated positions:
        (1) AFC switch to OFF.
        (2) BCN-RADIATE switch at WSP, if switch is set in this position, radiation must be turned off before changing.
        (3) STC switch at OFF.
        (4) ANTI-JAM switch at OFF.
        (5) ANTENNA switch at CW.
        (6) REC GAIN control at the position which gives the desired presentation on the plan position indicator.
    c. Turn the METER selector switch to MAG. The meter should read in the NORMAL portion of the scale. If the meter reading is abnormal, notify the technician.
    d. Turn the METER selector switch to CR1 (receiver crystal current).
    e. A steady meter reading indicates that the receiver is tuned. If the meter reading flutters, adjust REC TUNE to obtain a steady reading; then secure the REC TUNE knob. If a steady reading cannot be obtained, or if the reading is not between 0.4 and 0.6 milliampere, notify the technician.
    f. Turn the METER selector switch to CR2 (radar AFC crystal current). If the meter reading is not between 0.4 and 0.6 milliampere, notify the technician.
    g. Energize the echo box motor by depressing the ECHO BOX pushbutton switch. (This motor remains energized until the ECHO BOX pushbutton is again pressed.)
    h. Echo box ring time should be greater than 4000 yards for BCN-RADAR switch positions WSP, NLP, and WLP, with REC GAIN control set at full gain. If the ring time is less than 4000 yards for any of these positions, notify the technician.

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2. Beacon receiver tuning check: Follow procedures given for receiver tune.
3. Adjustment of STC controls: The STC controls require adjustment from time to time to allow for different conditions of sea return, depending on the roughness of the sea. The sea return appears on the plan position indicator as a solid disc extending radially for a range of several miles. The following procedure is suggested for an approximate setting of the controls. Final adjustments will probably have to be made by trial and error.
   a. Start the equipment.
   b. Tune the receiver.
   c. Set the REC GAIN control to obtain the best presentation on long-range targets.
   d. Turn the STC switch to ON.
   e. Turn the STC FLAT control near its midposition.
   f. Turn the STC DUR control fully CCW.
   g. Adjust the STC MAG control to break up the solid disc at the center of the plan position indicator into individual targets.
   h. Turn the STC FLAT control fully CCW so that the solid disc reappears at the center of the indicator. Then slowly turn the STC FLAT control clockwise until the solid disc barely disappears.
   i. Adjust the STC DUR control to best define the targets slightly beyond the solid disc.

Some ships have a policy requiring the operator to ask permission before tuning or adjusting the controls. If this is the case, follow the rules.

AIR-SEARCH RADARS

The primary function of an air-search radar is the detection and determination of ranges and bearings of aircraft targets at long ranges (greater than 50 miles), maintaining complete 360° search from the surface to high altitude. System constants must be selected with this function in mind. Low frequencies are chosen (P- or L-band) to permit long-range transmissions with minmum loss of signal. Wide pulse widths (2 to 4 microseconds) are used to aid in detecting small targets at greater distances. Low pulse repetition rates are selected for greater maximum measurable range. High peak power permits detection of small targets at long ranges. Wide vertical beam width is used to ensure detection of targets from the surface to relatively high altitude, and to compensate for the pitch and roll of the ship. Medium horizontal beam width gives fairly accurate bearing determination and bearing resolution while maintaining 360° search coverage. Some air-search radar characteristics and operational features follow.

AN/SPS-6B

The AN/SPS-6 series radar is presently the most common naval air-search equipment.

It replaces the SR series of air-search radars that replaced the SC/SK equipments. Frequency of the SR is the same as the SC/SK, but that of the SR-2 is 550 to 660 MC and that of the SR-6 is 1250 to 1350 MC. The output of the SR is 500 watts, the SR-2 is 350 watts, and the SR-6 is 500 watts.

The SR-6 is the only model presently of value to the operating forces. Many have been converted to the SR-6B, which is the same as the AN/SPS-6 series. In appearance the SR-6 and the SG-6 are almost identical. Their antennas, however, are different.

In the SR-6 the raising of the frequency and power from the values of the SC/SK models has given fewer fade characteristics and better target detection.

There are four models in the AN/SPS-6 series: the 6, 6A, 6B, and 6C. The only difference in the 6, 6A, and 6B is the construction of the antenna for determination of the vertical beam pattern. For the AN/SPS-6 the vertical beam pattern is 10°. The 6A has a 20° angle, and the 6B a 30° angle. The 6C is the same as the 6B except for a different antenna mounting and antenna control unit.

The frequency range of the AN/SPS-6 series is the same as that of the SR-6, but peak power is from 500 to 750 KW. The AN/SPS-6 series has two pulse widths, 1 microsecond at 600 PPS and 4 microseconds at 150 PPS. The horizontal beam pattern for all models is 3.5°.

All of the new search equipments are being designated with the AN/SPS nomenclature. In many instances these equipments are the same as present Navy model letter equipments with only minor modifications. One of these types is the AN/SPS-12.

AN/SPS-12

The AN/SPS-12 is similar to the AN/SPS-6 but includes a more sensitive receiver, a separate modulator, and a larger antenna.

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The AN/SPS-12 operates in the L-band frequency with a peak power output of 500 KW. The pulse repetition rate is 300 or 600 PPS, variable in either position, plus or minus 5%. The antenna rotates from 5-15 RPM's, and has a vertical beam width of 30° and horizontal beam width of 3.2°.

AN/SPS-17

The AN/SPS-17 is an air-search radar operating in the P-band with a peak power output of 1.5 MW with a PRR of 300 PPS. The antenna rotates at a speed from 5-15 RPM's, with a vertical beam width of 28° and a horizontal beam width of 18°. The antenna reflector is the bedspring type, sometimes called mattress type. In electronics texts the mattress (or bedspring) type of antenna is called curtain array.

AN/SPS-28

This set is installed on DD's and larger types. The appearance of the antenna (mattress) is the same as the AN/SPS-17. The frequency is in the P-band with a peak power output of 300 KW. The PW is 4 microseconds and PRR 120 PPS. This long-range air-search radar has a horizontal beam width of 18° and vertical beam width of 27°.

AN/SPS-29

The AN/SPS-29 is considered a typical type of air-search radar to be found on many ships of DD size and larger. It also uses the mattress antenna and works in the P-band frequency with a peak power of 750 KW. The PW is 10 microseconds and the PRF is 300 PPS. The horizontal beam width is 20° and the vertical beam width is 25.5°. This radar is similiar to the AN/SPS-17 and will receive much wider distribution in the fleet.

AN/SPS-32

This is a long-range air-search radar to be experimentally installed on the CGN-9 and CVAN 65. The antenna is a billboard-type built into the superstructure. The AN/SPS-33 is used with the AN/SPS-32.

AN/SPS-37

This set is another new radar that will be installed on DL's and larger types. It features a new method of operation called pulse compression technique. It is designed for very long range air search, and will use two antennas similiar to the AN/SPS-17 and 29.

FIRE CONTROL RADAR

The primary function of fire control radar is the acquisition of targets originally detected and designated from search radars, and the determination of extremely accurate ranges, bearings, and position angles of targets. The antennas must be tilt-stabilized to compensate for pitch and roll of own ship. Very high frequencies are chosen (X- and K-band) to permit the formation of narrow beam widths with comparatively small antenna arrays, detection of targets with small reflecting areas, and good definition of all targets. Pulse widths (0.1 to 3 microseconds) provide a high degree of range accuracy, short minimum range, and excellent range resolution. Repetition rates (1500 to 2000) afford maximum target detection while using narrow pulse widths. Since very long ranges are not required, low peak power permits the use of smaller components by keeping the average power low. Narrow vertical and horizontal beam widths (0.9° to 3°) provide accurate bearing and position angles and a high degree of bearing and elevation resolution.

Mk 25

The Mk 25 series of radar equipments was introduced in the late 1940's. They replaced the Mk 12/22 radars as the main secondary (AA) battery radars. The Mk 25 is a dual-purpose equipment and is for either surface or air targets.

Early models had a maximum range of 50,000 yards; later models, however, now range up to 100,000 yards.

The Mk 25 is an X-band radar with R-F peak power of 50 KW and a pulse width of 0.2 microsecond at 2000 PPS. The accuracy in bearing is plus or minus 0.1°. Range in yards is plus or minus 15 yards to 0.1 percent of the range. Elevation is plus or minus 0.1°.

Mk 34

The Mk 34 series of radars are X-band equipments and were first introduced about 1945. Their principal use is with heavy machinegun batteries; however, some models are used also

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with heavy AA batteries on certain types of ships.

The Mk 34 has a 0.5-microsecond pulse at 1800 PPS with a peak R-F output of 32 KW.

The antenna for this radar may be found mounted either on the gun platform itself (Mk 63 system) or on a separate director.

SUMMARY.—From the foregoing material on fire control radar equipments, four significant characteristics stand out: (1) narrow pulses, (2) low power, (3) relatively short ranges, and (4) high pulse rates. Added together they represent sharp, clear target resolution and accuracy of range and bearing.

Since new fire control equipments are classified, they cannot be discussed in this text. Classified publications covering these newer equipments are available from both BuWeps and BuShips.

Men in CIC work closely with Fire Controlmen, and you are expected to know the capabilities and limitations of your ship's fire control equipments, so make it a point to find out these features of your ship's fire control system from the Fire Controlmen.

ALTITUDE-DETERMINING RADARS

The primary function of the altitude-determining radar is to determine the accurate range, bearing, and altitude of aircraft targets detected by air-search radar. Its antenna must be tilt-stabilized to provide a stable reference for altitude determination. High frequencies (S-band) are chosen as a compromise between the long-range capabilities of lower frequencies and the narrow beamforming characteristics of higher frequencies. Narrow pulse widths (1 microsecond) are chosen to permit good range resolution. High pulse repetition rates (600 to 1000 PPS) permit detection of small aircraft targets at medium ranges (30 to 50 miles). High peak power is used to permit the detection of small aircraft targets at medium ranges while using narrow pulse width. Narrow vertical and horizontal beam widths (1° to 3°) are selected to permit accurate bearing and position angle determination and good bearing and elevation resolution. Following are some of the altitude-determining types of radars.

AN/SPS-26

The AN/SPS-26 is one of the newer types of height finders the Navy will install on ships of the DL class and larger. Much of the information is classified, therefore little can be told about it in this description. However, the PPI- and RHI-scopes are mounted side by side. The RHI, formerly called the VL-1, has been modified and is now the AN/SPA-31. The AN/SPS-26 uses the AN/SPA-32 remote repeater which is a modified AN/SPA-8 repeater.

The system uses a parabolic, cylinder-type antenna which is rotated electrically and presents a hemispherical scan.

AN/SPS-8

Radar Set AN/SPS-8 is a highpower, shipboard, height-finding radar system, designed for fighter aircraft direction. It presents target height, slant range, bearing, and beacon information on remote radar repeaters, and the model VL range-height indicator.

This radar is found on large ships (carriers and cruisers mostly) and many destroyer radar picket ships. It is primarily intended to be a fighter director radar, and must therefore be used with both PPI and RHI indicators. It is basically the same as other radars in that high-power R-F pulses are transmitted and subsequent echoes are received, amplified, and presented to indicators. Beacon responses are also presented if targets are equipped with the necessary transpondors. The transmitted pulse and indicators are synchronized so that range, bearing, and altitude of targets may be read directly from the indicators.

Most radars present only range and bearing, so their beams are narrow in azimuth and broad in the vertical plane. Altitude information from Radar Set AN/SPS-8 depends on knowing the exact angular position of the beam above the horizon when it is enveloping a target. The beam, then, must be very narrow vertically and its position must be independent of the ship's movements.

The first requirement is to move the beam up and down rapidly in more than 1.1° (the vertical width of the beam) to obtain the desired coverage. This is accomplished by the action of the scanner, Robinson feedhorn, and reflector. They cause the beam to sweep downward through an 11° sector which is variable between 0° and 36°, vertically.

The antenna is precisely stabilized by use of a stable element and the roll and pitch servo systems. The combined action of the antenna results in coverage of the selected 11° sector of sky through 360° in azimuth. Voltage representing the beam position is fed to the indicators, and, since indicator traces are synchronized

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with the transmitter pulse, the range, bearing, and elevation can be read directly from the indicators. Relative train, scan, and repetition rates are chosen to ensure 100 percent coverage of the 11° sector under surveillance.

Some of the operational characteristics of the AN/SPS-8 are: frequency in the X-band, peak power 650 KW, pulse width 1 or 2 microseconds, PRR 500 or 1000, CPS, and vertical beam width 1.1°, horizontal beam width 3.5°. Antenna rotation rates are 1, 2, 3, 5, or 10 RPM. It may be made to scan any sector from 30° to 200° or the antenna may be trained manually. Antenna elevation scan rates are 300, 600, and 1200 RPM.

Maximum range, using 1 MC/1000 CPS, is 83 miles; using 2 MCS/500 CPS, it is 165 miles. Minimum range is about 4500 yards.

Other Types

There are other types of Navy height finders that are now either operational or being developed. One of them is the AN/SPS-2, a long-range, stacked beam type of height finder, installed aboard the USS *Northampton* (CLC-1). Another is the AN/SPS-13, of which the Navy has one under evaluation. AN/SPS-34 is another that may be out soon.

SUBMARINE RADARS

Submarines, like surface vessels, require separate radars for air search and surface search. The present most common submarine surface-search radar is the Model SS series, which also serves as a torpedo control radar. The SS-2 has a frequency in the X-band with a peak power of 85 KW and a 0.5-microsecond pulse width with a PRR of 600. The BPS-9 is a later version of the SS-2 with practically the same operational characteristics.

The BPS-2 is a submarine air-search radar installed in SSR's. It is a medium-range, L-band, 500 KW power output radar. The pulse width is 1 microsecond or 4 microseconds, with a PRR of 600 and 150, respectively. It uses a parabolic type of antenna reflector with a horizontal beam width of 3.5° and a vertical beam width of 12°.

Space is of prime importance aboard submarines. Therefore, all submarine equipment is kept to the minimum in size for its operational requirements. Due to the submarine's low height when surfaced, ranges for its radar are relatively short and therefore great power is not required.

AIRBORNE EQUIPMENTS

Airborne radars are designed to meet the strict space and weight limitations that are necessary for all airborne equipment. Even so, airborne radar sets develop the same power that shipborne and shore-based sets are capable of producing.

As with ships, there are many models and types of airborne radar sets to serve many different purposes. Some of the sets are mounted in bomb-type enclosures suspended under the wings; others are mounted in huge blisters from the fuselage; still others are in the nose of the aircraft.

In fighter aircraft the primary mission of radar is to search for and help in the interception of enemy aircraft. Two types of presentation are available to the pilot of the fighter plane: (1) two-dimensional information (range and bearing) is presented in search operation, and (2) three-dimensional information (range, bearing, and relative elevation) is presented in intercept operation.

For normal operation the operator or pilot uses the search procedure. After contact he shifts to the intercept procedure, and obtains the relative elevation information which makes possible perfect intercepts.

Airborne radars, depending on the type of aircraft, may be either sector-scanning equipment (search only a certain sector width ahead of the plane) or may scan through 360°. The vertical widths of the scan beams are controllable to vary the upper and lower limits of the beam pattern.

Following are some of the general classifications of airborne radar: search and intercept, long-range search, short-range search, beacon, bombing attachment, bombing attachment or rocket firing, night search and intercept, and absolute altimeter.

The type of airborne radar you will be concerned with is the airborne early warning radar (AEW). The model used on most carrier-based type of planes is the AN/APS-20 series.

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Some of the important uses of AEW radar are as follows.

1. It can provide range and bearing of every object of destroyer size or above within its radar horizon. (The radar horizon is determined the same as for any other radar.) Information on targets detected can be passed by voice radio, CW, or by a radar relay from the AEW plane to a shore or surface station.
2. It can furnish strike groups with vectors to their targets.
3. It can detect and track single, low-flying bomber or patrol aircraft out to its radar horizon, except when severe sea return conditions limit minimum ranges. Within certain limitations it can control combat air patrol for the conduct of intercepts.
4. It can aid lost aircraft in returning to base.
5. It can detect a liferaft with corner reflector at about 50 miles in a sea condition of 2 or less.
6. It can detect such weather conditions as frontal areas and isolated storms.

Radarman 3 & 2, Volume 2, has instructions for operating the AN/SRR-4, used with AEW aircraft equipment.

ELECTRONIC EQUIPMENT OPERATING TECHNIQUES

To obtain maximum performance from your equipment, you must be familiar with the location, purpose, and use of all operating, tuning, and calibrating controls. You also should know some of the general principles that must be observed for proper care of ALL electronic equipment.

You will find that a large percentage of material casualties are the direct result of improper operation and abuse of the equipment.

Your duties as a Third or Second Class Radarman may include training other Radarmen or strikers in the proper handling of electronic equipment, whether it is radar, electronic countermeasures equipment, or perhaps the operation of radio direction finders. Once you demonstrate that you know how to handle the sets carefully by using the correct turnon and turnoff procedures and keeping the radars calibrated and tuned for maximum performance, the men will have confidence in you, and training others will become easier.

Following are some of the basic considerations with which all operators should be familiar.

STARTING EQUIPMENTS

Equipments which have had all power off for a considerable period require special handling. At this point it should be noted that, as a general rule, heater and temperature control circuits normally are kept energized except during extended shipyard overhaul periods or when repairs are required. When starting "cold," always use the turnon procedure recommended by the manufacturer of the equipment.

Temperature

Electronic equipment is designed to operate at relatively high temperatures. Vacuum tube filaments and cathodes must be allowed to reach their normal operating temperatures.

Vacuum Tubes

At normal temperatures, with normal grid and plate voltage, vacuum tubes emit a steady flow of electrons. These electrons constitute not only the normal plate current of the tube but also somewhat limit the emissions from the filament or cathode by setting up a space charge within the tube which opposes the flow of electrons from the cathode. If plate voltage is applied before the proper temperatures are reached, the space charge will be small or zero, and the initial surge of the plate current will be excessive. Over a period of time, the emissive material with which the cathode is coated will be taken from the cathode surface, and tube performance will slowly weaken. This results in a gradual reduction in equipment performance which is difficult to detect but which after a long period will cause the equipment to cease functioning. This condition will be worsened if the vacuum tube is forced to operate prior to reaching normal operating temperature. A review of chapter 2 of *Basic Electronics*, NavPers 10087, will help you in understanding this situation. Here are a few PRECAUTIONS that must be observed when turning on equipment.

1. Turn on filament or cathode switches, and let the tubes reach normal operating temperatures.
2. Turn on grid bias voltage switches.

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3. Turn on plate voltage switches.

NOTE.—In most cases, safety devices, such as time delay relays, perform step 2 and introduce a delay prior to step 3.

Resistors

All electronic circuits employ resistors to control and limit the flow of current. These resistors are designed to operate at a certain normal temperature. If the circuits are required to work before normal temperatures are reached, the flow of current will be too much in some cases and too little in others.

PRECAUTION:—Follow correct turnon procedure, step by step, and allow temperatures to reach normal before applying a load—that is, requiring the circuits to work.

Frequency and Stability

The frequency to which any circuit is tuned is determined by the constants of the circuit—capacity and inductance. In many cases the constants are changed by a difference in temperature. Consequently, frequency varies with a change in temperature.

PRECAUTIONS:

1. Keep all frequency controlling compartments at constant temperature by keeping heaters energized. Check thermometer readings frequently.
2. Follow correct turnon procedure and allow the circuits to reach normal temperature.

INDUCTIVE SURGE

When an electrical circuit switch is opened or closed, an initial surge of current results. The value of this current depends on conditions under which the switch is closed. If proper turnon and turnoff procedures are followed, the surge will not be excessive. If switches are thrown on or off at random, immediate damage may occur in some cases. In any event, over a long period, vacuum tubes, resistors, capacitors, relays, and other devices deteriorate, equipment performance falls off, and troubleshooting and repairs eventually are required.

PRECAUTION:—If the main power switch is opened when the equipment is fully operative, arcing occurs in the switch contacts. Remove the load before opening the main power switch, observing correct turnoff procedure.

Loss of Ship's Power

The power supply for the radar transmitters is furnished by the ship's generator. If the generator supplying power to the radars fails, an auxiliary generator can be placed on the line almost immediately. When the power supply fails, the scope of your radar becomes completely blank, resulting in no trace and no transmitted pulse on the A-scope. On the PPI, there usually will be a blob of light in the center of the screen, but all targets will be lost.

Many ships have an auxiliary power panel for the purpose of shifting the radars from one powerline to another. You must know its location and how to use it. If you've been selected to make the shift at the power panel, man the radar repair circuit phones at the panel and await orders from CIC. Do not shift until told to do so. If you shift too soon, you can cause damage to the radar repeaters as well as to the radars themselves.

If you're operating a radar or a repeater at the time of the power failure, immediately reduce the gain control and turn down all intensity controls. Report this fact to the radar control officer during general quarters and to the CIC watch officer during normal steaming. These precautionary steps are necessary to prevent the face of the scopes from being burned when the power comes back on. The CIC watch officer usually gives the order to shift power after he has made sure all the operators have taken the necessary precautions.

The same procedure has to be followed in shifting from the auxiliary generator back to the main generator. The operators go through the same steps of reducing the receiver gain and intensity controls. The man at the power panel again awaits orders before making the shift.

Changes in Line Voltage

Occasionally there may be changes in the power supply to the radars. Any sudden drain on the ship's power supply can cause the line voltage to drop, then rise quickly. For example, the power required to train the guns, or fire a broadside, can produce severe rise and fall in the voltage. Usually voltage regulators are installed along the line to hold the radar power supply as steady as possible. However, these regulators cannot completely eliminate power changes.

If the rise and fall is great enough, it may cause the radar to shut off automatically. When

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this happens you still can see a transmitted pulse on the scope, but no trace. Consequently all targets are lost. Most radars have a relay reset circuit designed to correct this situation. When your radar shuts off as a result of an overload on the power supply, it can be put back into operation by simply pushing the relay reset button on the main console. Before resetting the button, however, remember to reduce the gain and the intensity controls so that the scopes will not be damaged by burning the fluorescent coating on the CRT. Once the set is back in normal operation, you will have to retune the receiver to obtain top performance.

In many cases, although the voltage surge is not great enough to blank out the scope, it does detune the receiver. You can notice the voltage change by the wavering of the needle on the voltage meter and the change in the appearance of signals on the screen. Instead of a sharp, well-defined pip, the echo becomes ragged and decreases in size. When you see these signs, you can be sure that the receiver has become detuned.

Even though this detuning appears slight, it is important that you immediately take the proper steps to retune the receiver. You cannot get top performance with the radar out of tune. Promptness on your part in recognizing voltage variations will prevent making a false report that your set is not working properly.

RADAR TUNING

Willingness to tolerate substandard radar performance has become so widespread that the rare vessel which produces normal radar performance is looked upon as exceptional. Inferior radar performance has reached such a state in some instances that fleet and force commanders have issued specific instructions for procedures to detect and correct radar performance that is below standard. Many times the operator blames the gear for its inability to pick up targets when actually it is his own fault. Here we will explain how to measure relative performance of a radar. A radar should be tuned when measurements are not up to par, and the appropriate instruction book should be consulted before tuning.

TUNING DEVICES

Two simple pieces of equipment that more nearly resemble plumbing than electronic apparatus are provided, built in as part of modern radar, to permit measurement of significant performance factors. They are the slotted waveguide (with indicator) and the echo box.

Slotted Waveguide

The slotted waveguide, together with a pickup probe and meter, is used to measure the standing wave ratio. A slot is cut lengthwise in the wide axis of the waveguide somewhere near the transmitter. (See fig. 6-7.) This permits measurement of voltage distribution along the waveguide for a distance of at least half a wavelength.

Standing waves occur when power, generated by the transmitter and sent through the waveguide, is not radiated by the antenna, mainly because the antenna and waveguide are mismatched at the frequency the transmitter is generating. Energy not radiated is reflected back toward the transmitter, where the reflected energy encounters outbound energy in the waveguide and reacts with it to produce voltage (and current) nodes and nulls within the waveguide.

A high voltage standing wave ratio (VSWR) means that either the antenna or the transmission line is failing to radiate the power delivered into it.

Echo Box

The echo box, as the name implies, is a device that returns an echo whenever a pulse from the transmitter is fed into it. This echo is a standard echo in the truest sense of the word; if it changes, a change in over-all radar system efficiency is indicated.

The echo box consists essentially of a hollow cylinder (fig. 6-8), the size of which is varied by a plunger. Tuning for resonance is accomplished by moving the plunger in and out by its tuning knob. Energy from the radar transmitter is coupled into this tuned cavity in one of two ways: (1) A small pickup antenna, connected to the echo box by a coaxial cable, can be placed in the vicinity of the radar antenna. This is sometimes referred to as the indirect coupling method. (2) A waveguide directional coupler, shown in figure 6-8, can be installed to pick up energy that is fed through a coaxial cable to the echo box. Most radars use this system.

Usually echo boxes have an output meter built in as an additional refinement. This is used for making periodic comparisons of average pulse power.

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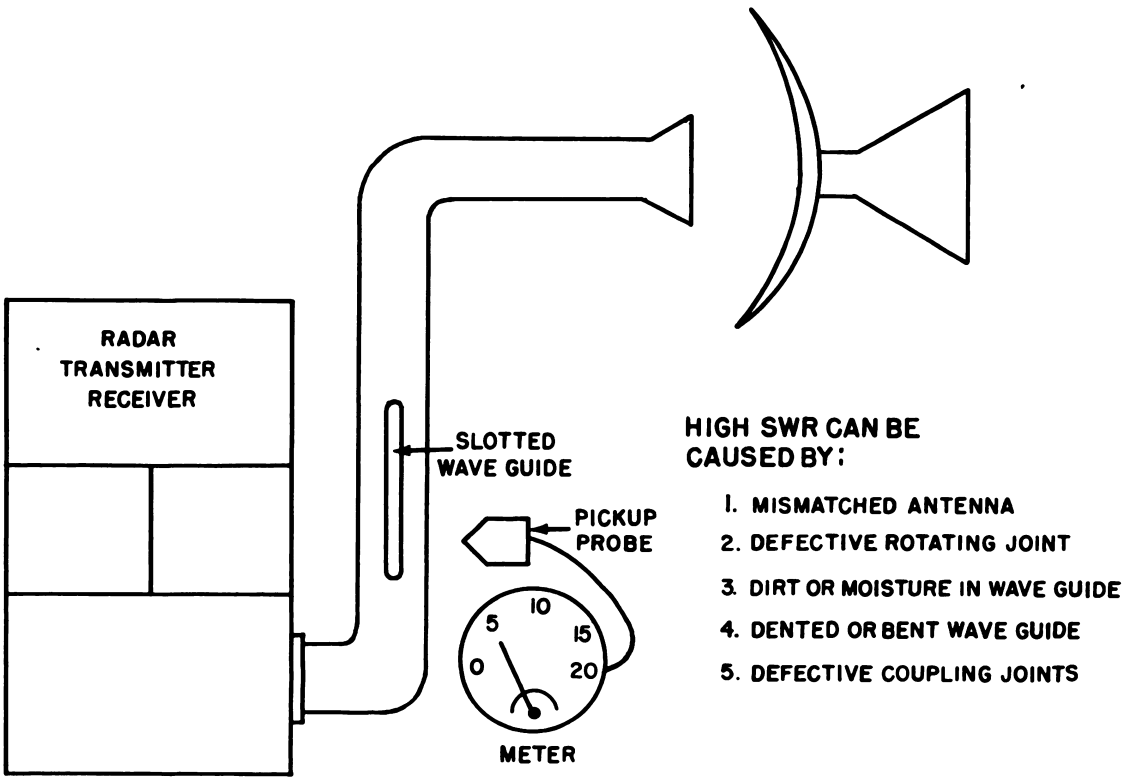

Figure 6-7.—Standing wave ratio indicator.

When the echo box is tuned to the natural frequency of the transmitter, and the receiver is properly tuned to the same frequency, resonance results, and maximum ring time can be expected. This ring time is displayed on the various indicators as a characteristic pip extending from zero range out to several thousand yards, depending on the individual radar.

With the indirect coupling method, the pickup dipole may be placed in a fixed position with respect to the radar antenna. In this case the echo box echo will be seen best in one direction only—when you train the radar antenna in the direction of the pickup antenna.

If the pickup antenna is attached to the radar antenna and rotates with it, or if a directional coupler is used, the echo will be seen extending in all directions from zero range to several thousand yards.

ECHO BOX PERFORMANCE MEASUREMENTS

Before the development of the echo box, radar operators had no way of testing the efficiency of their sets. A radar could have been in poor material condition, yet give fair ranges under conditions of nonstandard wave propagation. It is possible also for a set to be in good material condition and still fall far below the desired standard of performance. Thus, it is not possible to judge the efficiency of a radar accurately without testing it with an echo box.

Testing radar efficiency requires only a few minutes because the testing units are located near the transceiver, with an A-scope provided for monitoring the equipment performance and for tuning purposes. The echo box will be mounted either into the radar main frame or will be available as a portable unit. Measurements should be taken at the time a new watch is set or whenever you have reason to believe your set is below par. The procedure is as follows:

1. Turn on radar and allow sufficient time for it to warm up thoroughly.
2. Turn off antijamming controls and STC.
3. Rotate the radar antenna until it is pointed in a direction relatively free of targets out to several thousand yards.

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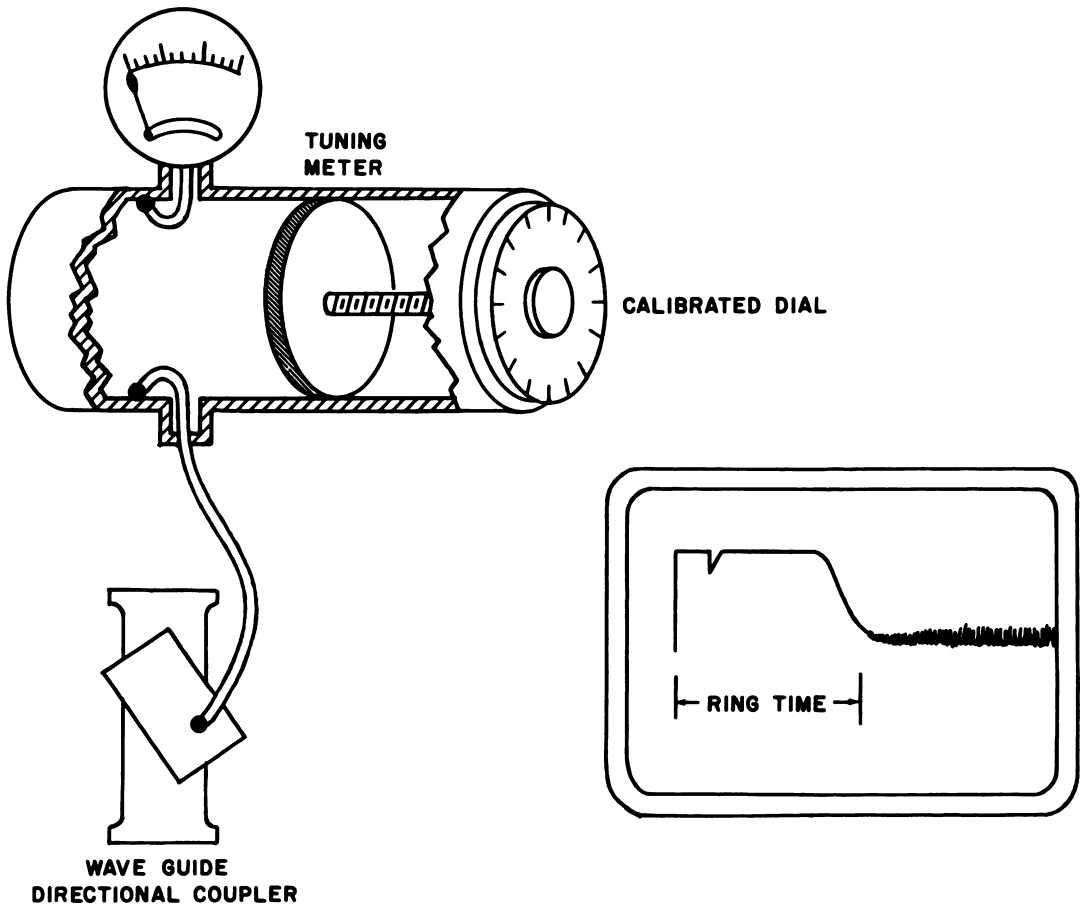

Figure 6-8.—The echo box radar ring time.

4. With echo box connected to directional coupler, adjust its tuning knob until the output meter reads maximum.
5. Check calibration of radar circuit.
6. Set receiver gain for short-range search.
7. Look at the echo box echo on the radar indicator (A-scope preferred), and adjust the receiver tune control until the echo box echo is saturated to the greatest possible range (fig. 6-8).
8. Measure the ring time several times and average the readings.
9. Record the date and time, output meter reading, ring time, and the difference between actual ring time and expected ring time.
10. If ring time is low, the technician should be called to investigate the trouble. A loss of more than about 150 to 250 yards of ring time begins to be quite significant (depending on the model of echo box used), especially with regard to small targets such as periscopes and aircraft. The radar material officer will inform the operators of the expected ring time, and may request that he be notified if loss of ring time is larger than some specified figure, such as 150 yards.
11. When you have completed the check, be sure to secure the echo box by detuning it.

Measuring Ring Time on A-Scope

In measuring ring time on the A-scope (fig. 6-9), the range should be read at the point where the echo disappears in the grass, and the antenna should be stopped. The echo box ring must not be confused with sea return or other nearby

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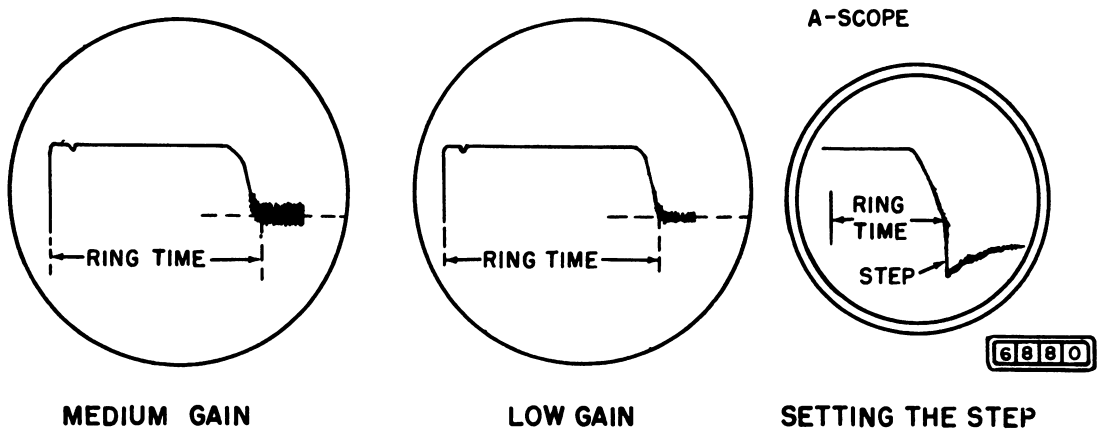

Figure 6-9.—Measuring ring time on A-scope.

echoes. The characteristic behavior will distinguish it from other echoes. Be careful of the receiver gain setting. A look at figure 6-9 will help decide where to set the gain.

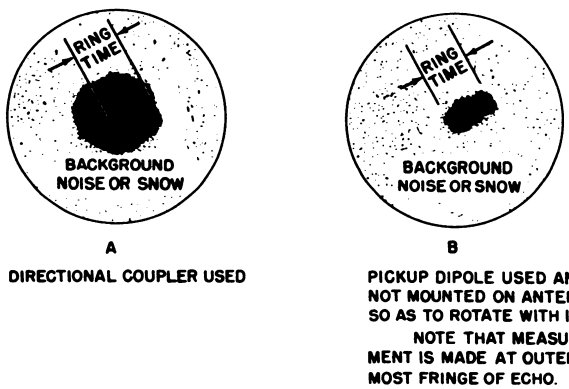
RING TIME
BACKGROUND NOISE OR SNOW
A
DIRECTIONAL COUPLER USED
RING TIME
BACKGROUND NOISE OR SNOW
B
PICKUP DIPOLE USED AND NOT MOUNTED ON ANTENNA SO AS TO ROTATE WITH IT.
NOTE THAT MEASUREMENT IS MADE AT OUTERMOST FRINGE OF ECHO.

Figure 6-10.—Measuring ring time on PPI.

Measuring Ring Time on PPI-Scope

When the PPI-scope is used (fig. 6-10), the ring time should be measured to the point where it is barely distinguishable from noise—not where it ceases to be solid white. Receiver gain should be set so that flecks of snow cover about half the scope area. Ring time then can be measured on the PPI with the antenna either rotating or stopped, but is generally easier when the antenna is in motion.

PRECAUTIONS:

1. The echo box merely indicates relative values, which, to have meaning, must be obtained under standardized conditions. In most cases, a number of operators will be measuring ring time. Organize the men in each section, assign a man in each section to a radar, and have them practice together until they can make readings that agree closely.
2. A high VSWR may place a voltage node at the echo box pickup, causing a high echo box reading and creating a false sense of well being. The VSWR must be brought within tolerance before the echo box can be trusted.
3. The transmitter pulse length, ganged with receiver bandpass, influences echo box readings. Be sure your operators take this into account and use the one which corresponds to the ring time expected. Expected ring time will depend upon whether the pickup antenna or the directional coupler is connected to the echo box. Narrow receiver bandpass and long pulse settings are recommended when taking echo box readings.

Additional Checks

Following are additional echo box checks. In most cases the technicians will make them.

1. TRANSMITTER POWER CHECK: Relative transmitter power may be obtained from the meter on the echo box. A more significant reading of power can be obtained from the magnetron current reading on the transmitter.

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2. RECEIVER SENSITIVITY CHECK: Energy reverberating within the echo box couples back into the receiver. This appears as a saturated echo at the beginning of the trace and gradually dies out.
3. TR EFFECTIVENESS: Examining the dip or depression of the echo box signal immediately following the transmitter pulse indicates TR effectiveness and tuning. A small dip indicates that the TR is satisfactory. A large dip indicates the TR action is unsatisfactory and damage to the receiver crystal can be expected.
4. OBTAINING TRANSMITTER SPECTRUM: Improper modulation of the transmitter will cause the transmitted energy to be dispersed over a larger portion of the radio spectrum than can be accommodated by the receiver bandpass. It then represents wasted energy for echo purposes. The transmitter spectrum can be determined by walking the echo box tuning across the transmitter output and measuring the power at various frequencies. A graph of power versus frequency will show the transmitter spectrum.

Voltage Standing Wave Ratio (VSWR)

For VSWR measurements, move the pickup probe along the slotted waveguide and take maximum and minimum readings. The ratio of maximum voltage to minimum voltage is called standing wave ratio and is the measure of the antenna and transmission effectiveness in transferring power.

The prescribed Navy standard is that the standing wave ratio must not exceed 1.5 to 1.0. A higher value indicates too much energy is being lost within the system. The ideal—that is, no maximum and minimum—indicates perfect transfer of power and is called a flat line.

After making the adjustments described, if the VSWR is still excessive, trouble in the transmission line is indicated. The waveguide should be checked for water deposits, dents, nicks, excessive corrosion, or badly fitting joints. Should the VSWR change as the antenna rotates, a bad rotating joint is indicated.

RECORDING DATA

Information obtained by the measurements described below should be recorded for comparison and evaluation of radar performance. Readings other than standard become readily apparent, and corrective action can be taken immediately.

Ring Time

It is recommended that a graph be plotted of radar ring time on an hourly basis. (See sample graph, fig. 6-11.) Yards of ring time can be plotted on the Y-axis (vertically) and hours of the day on the X-axis (horizontally). A red line should be drawn 150 yards below normal ring time. This represents loss of 15 DB of radar performance, or about 50 percent of radar detection range. Radar ring time must not be allowed to fall below this level.

Voltage Standing Wave Ratio

Since VSWR should not be allowed to rise above 1.5 to 1.0, and radar ring time should not be allowed to fall, both can be drawn on the same graph, using the bottom portion to plot VSWR. (See fig. 6-11.) A red line at 1.5 indicates the value that VSWR should not be allowed to exceed.

TUNING CONTROLS

There are only three tuning controls on a radar: transmitter magnetron, receiver oscillator, and duplexer. Because radars drift off frequency and out of tune, settings on these controls should be checked on a watch-to-watch basis, or before any action or exercises, to return the system to normal. To make the checks, only the echo box and VSWR indicator are needed.

Transmitter Magnetron

Radar antennas are frequency sensitive, accepting power at only one frequency. The technician usually determines this transmitter frequency by using the echo box as a frequency meter, by walking the transmitter through its tuning range in small steps, measuring the VSWR at each point. The frequency at which minimum VSWR is found is noted, then the echo box setting is marked in grease pencil on the panel, so that, when you have to tune the transmitter, all you have to do is adjust the transmitter to the echo box setting. Where nontunable magnetrons are installed, select the type that falls nearest this frequency. After tuning, check the VSWR to assure it is satisfactory, and indicate value on graph.

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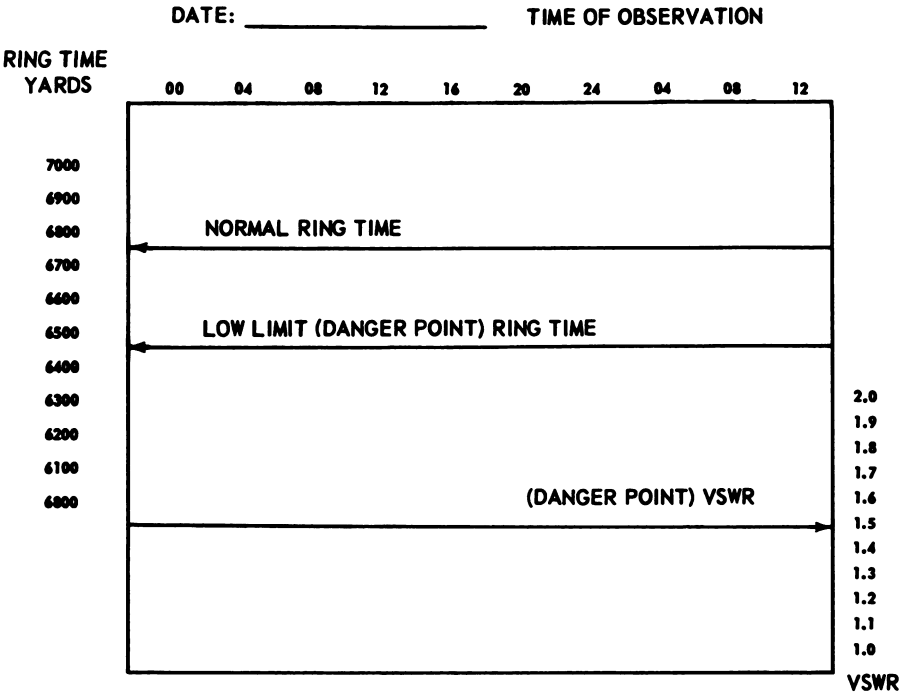

Figure 6-11.—Ring time and VSWR readings.

Receiver Tuning

If your radar receiver is slightly out of tune with the transmitter, you will receive small, weak pips on the indicators. Tune your radar so that it will produce the largest pips on the oscilloscope screens.

Some radars have the settings of the tuning dials predetermined by the technician. To tune such a radar, all that is necessary is to set the dials to the indicated positions. Your receiver is then tuned correctly.

If your radar does not have these indicated settings, or if the settings are inaccurate, it will be necessary to tune the radar receiver so that you will get the largest pip from a detected target.

The best type of echo to be used in tuning your receiver is one that is received from a land target. This type of pip will be stationary and will not bob up and down. Stop the antenna so that it will be pointing directly at the target. In manual tuning, at the general control unit of the radar, adjust the receiver tune control until targets appear on the range scope. If targets appear to fade and then become brighter when the antenna is stationary, adjust the receiver tune control for stable operation. Set the control in the middle of the stable range.

If targets do not appear, snap the AFC manual switch on the receiver to MANUAL. Then adjust the receiver tune control on the general control unit for maximum signals. Check the setting of this control frequently while using manual tuning because the AFC circuit is disconnected and drifting may occur.

If land targets are not available, tune on a ship target. The method is the same as that used for tuning on a land target. A ship target is less satisfactory because target echo is inclined to bob up and down, and therefore cause more difficulty in determining the maximum pip. This is owing to the variance in effective reflective surfaces due to ship movement.

In the absence of both ship and shore targets, sea return may be used, but this is the least satisfactory method of tuning. Set your radar to the shortest possible search range and proceed as before. The sea return will appear close to your ship. The receiver gain control should be adjusted so that it is just low enough so that the pip is never driven to saturation.

In the absence of targets, or at the discretion of the RD 3, the receiver can be tuned with the aid of the echo box. On the AN/SPS-10, the echo box is tuned remotely by the echo box motor, which tunes the echo box over the entire frequency range covered by this equipment.

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To tune the receiver by using the echo box, press the echo box test button on the general control unit. Throw the AFC on/off switch to OFF. While observing the PPI screen, and with the receiver gain control set at or near maximum, adjust the receiver tune control for maximum artificial echo signal.

With the antenna stopped (antenna control switch at OFF), the signal will appear as a solid line extending out from the center of the screen to about 2 miles. With the antenna rotating in a clockwise direction, the signal will appear as two egg-shaped lobes extending out from the center of the screen to about 2 miles. This picture is the result of tuning the echo back and forth through resonance.

Release the echo box test button and return the AFC manual switch to AFC.

The set is now tuned and ready for searching.

It should be noted here that tuning using ring time is preferable to tuning using sea return.

Duplexer Tuning

Duplexer tuning is normally done by the ET. However, if you have to do the tuning, proceed as follows. With the echo box still in, tune the duplexer TR box for maximum ring time and the ATR box for minimum dip, as seen on monitor or A-scope. The ring time reading may be taken by aligning the A-scope range notch with the point where the ringing signal falls to the noise level of the receiver. This value is then recorded on a graph.

CHARTING MEASUREMENTS

Tuning adjustments and measurements can be performed quickly and easily by the radar operator. Making a graph of the readings gives a clear and reliable index of radar performance. If the radar operator is unable to bring the readings within the prescribed limits, need for corrective action is indicated, and the Electronics Technicians must be called in.

The performance chart shown below gives the necessary checks for keeping radar performance as high as possible. These checks are divided between the operators and the technicians, and emphasize the cooperation needed in obtaining maximum radar performance.

These measurements will be of little value unless they are charted properly and frequent comparisons of data are made. Any variations from standard performance must readily be noted so the system may be returned promptly to normal.

It is recommended that a graph be plotted in CIC, with ring time in yards plotted against time. The suggested graph can be maintained in CIC on a visible status board. A red line is drawn at the danger points, below which points performance must be checked. The graph shows a plot of VSWR and ring time with the danger points at 150 yards below normal ring time and at 1.5 on the VSWR scale. Different colors represent the various radars on board.

The following hints are suggested for using ring time and VSWR readings.

Performance Chart

Quantity checked	Who checks	How Often	Worth of measurement	Time required	Remarks
Receiver sensitivity.	ET	Weekly	Excellent	Approx. 10 minutes.	Checks should become routine.
Power output.	ET	Weekly	Very good	Approx. 10 minutes.	Substitute meter readings at Xmter if no power meter.
Ring time	RD	Each watch as tuning indication.	Good	5 minutes	Rough performance indicator only.
VSWR and magnetron spectrum.	RD	Daily	Good	3 minutes	Supplements radar performance measures.
Waveguide and antenna check.	ET	As performance variable indicates.	Variable	Variable	Should already be in PM schedule.

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1. Check transmitter, receiver, and duplexer tuning hourly (if possible).
2. Check the transmitter against the proper frequency as previously determined by VSWR and echo box readings.
3. The echo box is a frequency meter.
4. Tune the receiver (after tuning the transmitter).
5. Tune the duplexer for maximum ring time and minimum dip on monitor or A-scope.

QUIZ

1. What is the purpose of a switchboard?
2. What is the name of the auxiliary electronic system that is tied to every search radar for distinguishing between friend and foe?
3. How is the information produced by the auxiliary electronic system fed to the same repeaters as the video from the parent radar?
4. Describe the difference between the SG-6B and the SG-1B radar antennas.
5. How does the AN/SPS-4 differ from the SG-6B radar?
6. Name the radars listed that you would most likely find on small boats or small craft.
7. What kind of radar was the AN/SPN-21? (See nomenclature section in chapter 2.)
8. Name an outstanding feature that the AN/SPS-5 had.
9. What is the radar horizon (in miles) of a radar that has an 81-foot high antenna?
10. What is the function of the band suppression filter on the AN/SPS-10 radar?
11. Where is the echo box located on the AN/SPS-10 radar?
12. Name two ways the echo box can be tuned on the AN/SPS-10 radar.
13. What single unit of the AN/SPS-10 contains all of the necessary controls for operating the radar system?
14. What name will the unit have that contains all the necessary controls for operating on some of the other radars?
15. What circuit in the radar receiver maintains the local oscillator frequency 30 MC higher than the transmitter magnetron frequency in order to keep the receiver signal at the I-F input centered on 30 MC?
16. What circuit in the receiver reduces the gain of the receiver at the same time the transmitter pulses, then rises gradually to normal?
17. What is the value of the above-mentioned circuit?
18. What circuit in the receiver makes it possible to distinguish more clearly individual targets in a cluttered area which otherwise would appear as a large mass on the PPI?
19. What unit delivers true bearing (own ship's course) information to the PPI?
20. How does the AN/SPS-12 differ from the AN/SPS-6?
21. What type of radar is the Mk 25?
22. What maximum range can you expect from the Mk 25?
23. What is the purpose of the AN/SPS-8 radar?
24. What is the BPS-2 and where would you find it installed?
25. What is the range to the radar horizon of an AEW plane at 10,000 feet altitude?
26. At what range can you expect an AEW plane flying at 10,000 feet to pick up a target at a height of 81 feet?
27. What is the usual visual indication of a power supply failure on the A-scope?
28. When is power shifted from normal to emergency?
29. What is the first thing the operator should do prior to shifting from one powerline to another?
30. (a) If a voltage change does not "blank" the scope, what effect does it have on the receiver?
    (b) How do you know the receiver has been affected?
31. (a) For what purpose was the echo box designed?
    (b) In what other manner can you keep a check on the performance of your radar?
32. When and how often should you make use of the echo box?
33. What should the receiver gain setting be for echo box work?
34. In question 33 above, where should the antenna be trained? Why?
35. What is the purpose of the receiver tune dial in using the echo box?
36. After reading the ring time, what steps must be taken?
37. When is the ring time loss considered significant?
38. What is the prescribed Navy standard concerning voltage standing wave ratio?

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CHAPTER 7

PLAN POSITION INDICATORS

REMOTE PLAN POSITION INDICATORS

First to be discussed in this chapter will be the need for and advantages of remote radar indicators. Second, you will be acquainted with the principles of the shipboard distribution system for sending radar information to remote indicators. Finally, we will take up some of the types of repeaters now found aboard ship, cite general rules that have been established for the operation of all repeaters, and list operating steps for some of the repeaters installed in ships today.

In the previous chapters we discussed the various types of scans and the mechanics of developing them. The remote plan position indicator is a unit which is capable of operating, by selection, with any of the search and height-determining radars in use today.

NEED FOR REMOTE DISPLAY

In the early days of the military use of radar, the display of its information was confined to a single unit called a console. It included, in addition to the indicator and its associated controls, a number of receiver and transmitter remote controls. As the development of radar progressed, individual ships were furnished with more than one type of radar (air-search, surface-search, etc.), and it became more and more apparent that the information from these equipments would have to be displayed at any one of several physically separated stations. Coupled with this, size and weight restrictions made the relatively bulky and complex console unsuitable to remote installation. Therefore, a smaller, lighter, general-purpose unit, capable of accepting inputs from more than one type of radar, was needed. In addition, operating conditions required that the same radar information be displayed in more than one way to perform more than one function at the same time. (For example, the information from an air-search radar might be used for air search and air control at the same time, each requiring a different type of display.)

The present-day remote indicator is an equipment fulfilling the needs already mentioned. Several types of these indicators and the associated system used for distributing the radar information available to any given indicator follow.

TYPES OF REMOTE INDICATOR PRESENTATIONS

There are many types of radar presentations, but only those which are applied to the CIC situation will be taken up here. These are: standard PPI, projection PPI, large diameter PPI, delayed PPI, and range-height indicator. The selection of the following types of presentation for this application is based on three considerations: (1) type of information to be presented, (2) use to which the information is to be put, and (3) type of radar involved. The Radarman may assume that, of the many types of display available, the ones given here are considered those most representative for CIC at the present time.

The types of repeaters most likely found on ships today are the models VJ, VK, VN, VG, VL, and VF (which is becoming obsolete), the AN/SPA's 4, 4A, 8, 8A, 8B, 8C, 9 (the AN/SPA-9 is no longer in procurement), 22, 23, 25, 31, 32, 33, and the 34. Many new models are being perfected and will be placed on a large number of ships in the future. In general, most of them will be only modifications to the types discussed in this chapter. Therefore, if you master the ones listed here, any others, completely new or modified, can be learned with little effort. Before going into details of these various types of repeaters, let us look at the requirements of the system.

Radar Distribution System

Several inputs are necessary to operate radar indicators. First, video information (that is,

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target echoes) must be supplied to the scope for display from any one of several radars that may be available. Next, azimuth synchronizing information must be furnished in order to make accurate bearing information available. To north stabilize the indicator, that is, to enable the operator to read true bearings directly from the mechanical cursor or bearing counter, two types of bearing information must be combined. These are the direction of true north supplied by the ship's master gyro, and the relative bearing toward which the radar antenna is pointing at any given moment. They are combined and the algebraic sum derived. This information is fed to the PPI-scope, allowing the direction in which the sweep is pointing at any given time to be fixed in relation to true north. With the top of the indicator always north, bearings can be measured with ease. The final input that is necessary for indicator operation is the sweep trigger. This is merely a timing pulse from the timer of the radar which sets the sweep or time base of the indicator in motion in sychronization with the pulsing of the radar transmitter.

Inasmuch as modern naval ships are equipped with several radars and many indicators for display of their target information, the problem of getting the information from any radar to any PPI must be solved. The most obvious solution would be to run a cable from each radar to every indicator, but this would require too much weight and space. Therefore, a centralized distribution system was devised, consisting of a distribution panel with a single cable input from each radar and a single cable output to each indicator. A call light system, energized from the remote indicator, indicates the desired radar at the distribution board. The corresponding selector switch on the board is matched to the call light and the circuit is completed. A video amplifier arrangement is included to assure adequate video signal strength. This has proven to be a very reliable system, and requires a minimum of weight and space.

One of the Radarman's maintenance duties is to keep faulty light bulbs replaced, as they are constantly burning out. A good idea is to keep a plentiful supply in CIC or a handy space.

BASIC REMOTE INDICATOR

All indicators are basically the same. It is in the method of presentation, and the various special electronic circuits required to develop the presentation, that they differ. It is not the purpose of this chapter to deal with the electronic aspect of remote indicators, but to discuss the methods of presentation. The remote indicator is not in itself a radar. Rather, it is a radar repeater, and it depends on the radar for three things: (1) synchronism (timing), (2) video information (the pip or echoes), and (3) antenna direction (azimuth or bearing).

TRIGGER PULSE

We know that the indicator scopes must be synchronized with the outgoing pulse of radio energy in order to measure the time between that pulse and the returning echo. The same pulse that times the radar indicator is also applied to the remote indicator to start its sweep at the same time. This is called the trigger pulse.

VIDEO

The returning echo energy must also be supplied to the remote indicator to form pips. These pips are called video, and are supplied to the remote indicator scope in one of two methods of data presentation. They are deflection presentation or A-scope, and intensity modulated presentation such as the PPI-scope.

ANTENNA INFORMATION

It is also necessary that the remote indicator sweeps be synchronized in azimuth with the antenna of the main radar. This is so that the azimuth or bearing at the remote indicator will agree with the correct bearing as observed at the indicator of the radar. This antenna information can be either true or relative.

SELECTOR SWITCHES

The three types of information described are supplied to the remote indicator by all radars that will be repeated by that indicator. They are applied through a selector switch that selects the trigger, video, and antenna information desired.

STANDARD PPI'S

The use of repeater indicators permits great flexibility in radar operation. Generally, the repeater can be connected to any of the search radars aboard ship. Most of the standard repeaters now in operational use are provided

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with a 10-inch CRT and employ range scales such as 2, 4, 10, 20, 80, and 200 nautical miles, though some repeaters have continuously variable scales. Most models have facilities for the generation of a range ring incorporated in their circuits. Thus, the range of the target can be read directly from range counters geared to the knob which controls the strobe. Range accuracy depends upon the repeater's own range circuits but can never be better than that of the controlling radar.

The resolution (ability of a radar to resolve or separate two or more targets at the same approximate bearing and range) of a repeater PPI is controlled primarily by the characteristics of the radar to which the repeater is connected, but the range scale used may also affect range resolution to some extent. For example, a short-range scale on the repeater PPI will provide better resolution of near targets than is possible if a long-range scale is used. Bearing resolution cannot be improved by the use of the repeater PPI, since this characteristic is controlled primarily by the beam width of the radar antenna.

The range resolution of which any PPI is capable on long-range scales is relatively poor. This failing is caused by the limitation of the minimum spot size that can be produced on the screen of the cathode ray tube. For example, on a 12-inch tube, 1 microsecond occupies only 0.0025 inch of the 200-mile range scale, while the minimum spot of light that can be produced on the screen may be about 0.03 inch in diameter. Under these conditions, even a 1-microsecond pulse would appear to be a mile wide, so that the PPI is far from able to display the resolution of which the radar is capable. On a shorter range scale, such as the 10-mile range, for example, the spot size is small enough in terms of yards so that it does not limit the resolving power of the PPI, and the range resolution is greatly improved. Therefore, if it were possible to delay the start of the sweep for a time equal to 50 miles, for example, targets at 56 miles could be viewed on the 10-mile scale with good resolution, instead of on the 80-mile or 200-mile scale with relatively poor resolution.

Overcoming this difficulty is the main purpose of the special features now being incorporated in practically all modern repeaters with off-centering, delay, etc.

REMOTE INDICATOR AN/SPA-4A

The AN/SPA-4A is a standard PPI type repeater used for the most part for surface search and station keeping. It uses a 10-inch, flat face, cathode ray tube to show range and azimuth of a target. It is a self-contained unit designed for operation with any standard Navy search radar system having a pulse repetition frequency between 140 and 3000 PPS. This repeater may be employed to select radar information from any one of several radar systems. A variable rubber range control is incorporated, whereby the range may be continuously varied from 1 to 300 miles.

GENERAL RULES APPLICABLE TO ALL REMOTE INDICATORS

Certain basic controls are common to all remote indicators the adjustment of which follows a set order. Therefore, a basic set of rules for turning all indicators ON and OFF can be established. Following is the turning-on sequence.

1. Make sure all intensity and gain controls are turned down counterclockwise. This is to prevent a "surge" of voltage in the cathode ray tube which might damage its viewing screen.
2. Place power switch in STANDBY then to OPERATE after prescribed delay period has intervened. Delay is necessary to allow certain tube filaments and circuits to warm up. Applying operating voltages to cold tubes and circuits might damage them. Some equipments are furnished with automatic, built-in time delay circuits.
3. Select radar desired.
4. Turn up intensity until sweep is visible.
5. Focus as necessary for sharp, clearly defined sweep.
6. Reduce intensity until sweep is BARELY VISIBLE.
7. Turn up video gain until targets are clearly visible, or, in the absence of any targets, until "snow" is clearly visible. (Snow on a PPI corresponds to grass on an A-scope.)
8. Turn up auxiliary intensity controls (for example, range markers, range ring, electronic cursor, etc.) as desired.

Following is the turning-off sequence.

1. Turn all video gain and intensity controls down (counterclockwise).
2. Turn radar selector to OFF.
3. Turn off all dial lights.

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4. Turn power to STANDBY or OFF position as local policy dictates. (In many air-conditioned CIC's the power switches are not placed in the OFF position because practice has shown that the repeaters will remain in calibration better if the repeater stays at the same temperature all the time. However, if your ship is to be in port for any length of time and the repeater is not being used constantly, it is best to place it in the OFF position.)

Differentiation Between Video Gain and Intensity

To distinguish between the two functions, video gain and intensity, it is well to reexamine the A-scope presentation. You remember that the time base on an A-scope without any video imposed upon it appears as a thin, straight line across the face of the tube. (See fig. 7-1, part A.) In that situation an increase or decrease of the intensity control setting would increase or decrease the brightness of the time base. Normally, intensity on a PPI should be set so that the sweep is barely visible. Now, with the addition of video, the foregoing picture will result in two changes. First, grass will appear along the base-line; this results from noise in the receiver and corresponds to snow in the PPI presentation. Second, targets appear as pips which correspond to the bright pips on the PPI (see fig. 7-1, part B). If you can imagine the A-scope presentation as it would appear in a top view rather than the side view as illustrated in figure 7-1, the basis of the PPI display will be apparent. The functions of intensity and gain are the same in both situations; they are merely being viewed from different angles.

While the intensity setting is normally kept so that the sweep is at the threshold of visibility, the video gain setting must be varied according to the size and range of the targets being scanned at any given time. In general, short-range work requires less gain than long-range work. Actual experience is the best teacher in this connection, and you must take advantage of every opportunity when not on watch, or during remote indicator operational checkouts, to acquire the necessary experience.

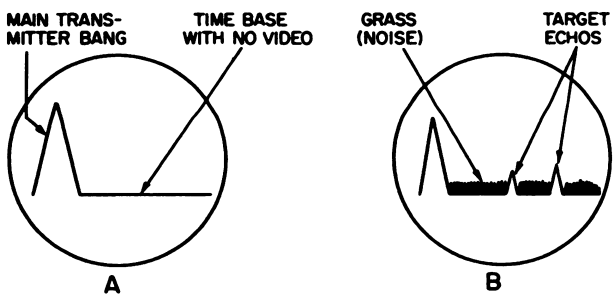

Figure 7-1.—Video gain and intensity on A-scope.

Accessory Devices for Simplifying Repeater Operations

A number of features common to many indicators have been provided to make rapid and accurate interpretation of the radar picture easier. The efficient operation of these devices greatly improves the value of the indicator as a major source of information in CIC. The following is a list of these features with a short description of the function of each.

1. Mechanical and electronic cursors—for the measurement of bearings on all types of PPI repeaters.
2. Relative bearing warning light—indicates that the gyro input has failed and that all bearings are relative rather than true.
3. Battle short switch—bypasses all safety interlocks in the high-voltage circuit to prevent main battery gunfire from accidentally opening them. Interlocks are provided on all electronic equipment using high voltages to protect personnel from accidental injury.
4. Reflection plotter—a device enabling the operator to plot targets directly on the face of the cathode ray tube without actually touching the tube, and without parallax.
5. Target designation buzzer—a signal system between the remote indicator and fire control radar on target. Indicates the bearing and range of the target to the fire control operator.
6. Dual azimuth rings—one is fixed for reading true bearings, and the other is movable to set in magnetic variation so that magnetic bearings may be taken. This is necessary in order to make accurate air control possible, because only magnetic compasses are available in present-day fighters and interceptors.
7. North stabilization—true north appears at the top of the indicator at all times, making bearing determination easier.

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PRECISION PPI REPEATERS

The VF remote indicator is a precision repeater that has become obsolescent on active ships and has been generally replaced with the AN/SPA-4 series. The VF was designed to repeat at a remote point with a high degree of accuracy the information given by master surface-search radar equipment. The targets are presented on two identical 5-inch cathode ray tubes.

The first of these display tubes is used as a conventional PPI tube, employing standard ranges of 4, 20, 80, and 200 miles, and providing range mark spaces at corresponding intervals of 1, 5, 20, and 50 miles. Range is read radially on the PPI sweep. Azimuth angle (true bearing) is read angularly on the inner of the two PPI dials at the point where the cursor bisects the dial scale. Relative bearing is read against the outer PPI dial.

The second display tube is used as a B-scope which reproduces a selected segment of the PPI screen in greatly enlarged form. This enlarged presentation being a rectangular coordinate view, the vertical sweep on the B-scope represents range; the horizontal sweep represents azimuth angle.

The range accuracy is ±25 yards between 4000 and 50,000 yards and ±100 yards between 500 and 4000 yards.

The bearing accuracy is ±0.15° (master radar governs). The skill with which you align the bearing cursor, plus the range of target, also contribute to the bearing accuracy of the VF. This holds true for any repeater.

The special feature of this precision-type repeater is the B-presentation that may be used for navigational purposes. It also is used as auxiliary fire control.

The turnon and turnoff procedures and operating technique will not be given, as this equipment is in the process of being replaced. Information included here is only for information and to bring you up to date on the advancement of repeaters.

PROJECTION PPI

The models VG, VG-1, VG-2, VG-3 are projection-type repeaters designed to provide radar information directly to a horizontal plotting surface for the surface plot function. The plotting surface can be used (1) to plot surface contacts, (2) for station keeping, and (3) as an aid to radar navigation.

The VG indicator (and modifications) uses a very brilliant, sharp definition, 3-inch cathode ray tube with an optical system which magnifies the radar picture to a 24-inch diameter and projects it against the underside of a frosted glass surface plot. Targets are displayed on the CRT in dark purple against a light background so that the resulting picture on the plotting surface is light enough to make it suitable for plotting. The CRT is of exceptionally long persistence and is equipped with a special erase control to eliminate residual target display such as those resulting from changes in range scale.

Unfortunately, several weaknesses have shown up in the operation of this equipment which seriously limit its usefulness. First, the life of the CRT is quite short due to the very high intensity needed for projection purposes. Second, the optical system proved to be too delicate, and realignment required specialized training. Third, the erase feature did not function properly. However, modifications have been developed to correct these weaknesses, thus making the indicator much more reliable. Most present-day VG's are employed as maneuvering boards, using only the plotting surface and lights for keeping formation diagram and surface plots.

LARGE-DIAMETER PPI'S

A principal disadvantage of the projection PPI is the poor pip definition due to the magnification system used. To eliminate this deficiency, however, a large-diameter PPI, known as the VN, has been developed.

The VN radar repeater provides a large, general-purpose, direct-view display with a 20-inch PPI, and is designed for operation with any standard Navy search radar system. It is equipped with a type 20-BP-7 long-persistence CRT, in which both focusing and deflection are done magnetically.

The VN contains all the characteristics of the VK model PPI, including an electronic cursor and strobe.

DELAYED PPI

A variation of the standard PPI presentation is the delayed PPI. The VJ remote repeater uses this special feature, in which the sweep is delayed for a time equal to the range at which the operator desires the picture to begin. Then the sweep covers the rest of the desired range in the normal manner. In other words, if a sweep

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normally starts at zero range and extends to 10 miles, it will start at 50 miles and extend to 60 miles if the start of the sweep is delayed a time equivalent to a range of 50 miles. In figure 7-2 (part A) a normal 40-mile PPI picture is seen. Let's assume that the operator desires to expand that portion of the picture from 15 to 25 miles for a closer look. When the scope is switched to delayed operation, the portion of the presentation from 15 to 25 miles through 360° in azimuth will occupy the entire face of the indicator. (See fig. 7-2, part B.) The advantage of the delayed presentation is better target resolution. It allows the operator to expand the target area for more detailed information of the characteristics of that target. However, there is one serious disadvantage connected with the delayed picture due to the way in which it is generated, and that is that there is considerable distortion introduced. It is most strongly seen in bearings and ranges between targets. The bearings and ranges from one's self to any given target remain accurate. The distortion between targets makes it difficult—if not impossible—to perform effectively while air-controlling on a delayed presentation. Therefore, it is seldom used for that purpose. Also, when using the delayed operation, accurate ranges cannot be taken, because moving the range crank moves the amount of delay introduced, so that ranges have to be made by estimating with range marks as references.

MODEL VJ REMOTE INDICATOR

The VJ is a remote indicator designed for use with any type of search radar equipment capable of transmitting PPI information. Its purpose is to repeat, at a remote position, target information appearing at any selected master radar system. Provision is made for transmission of range and bearing information of chosen targets to other remote points, when designated.

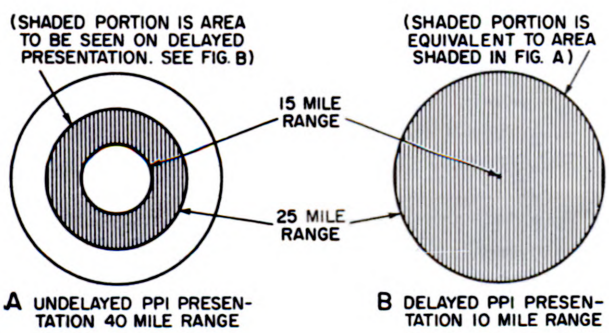
(SHADED PORTION IS AREA TO BE SEEN ON DELAYED PRESENTATION. SEE FIG. B)
(SHADED PORTION IS EQUIVALENT TO AREA SHADED IN FIG. A)
15 MILE RANGE
25 MILE RANGE
A UNDELAYED PPI PRESENTATION 40 MILE RANGE
B DELAYED PPI PRESENTATION 10 MILE RANGE

Figure 7-2.—PPI delayed operation.

Figure 7-3 shows the operating controls of the VJ. Targets are presented on a conventional 12-inch PPI tube. A valuable feature is the provision for a delayed sweep, which permits enlargement of distant targets on the PPI screen for closer examination in estimating target composition. Six range settings are available: 2, 4, 10, 20, 80, and 200 miles. Four fixed range markers are provided on each range setting, each marker representing one-fourth the distance of the range setting used.

Other general characteristics are:

1.	Range scales:	Undelayed operation 2, 4, 20, 80, 200 miles. Delayed operation 10- or 20-mile sector up to 200 miles.
2.	Center expand:	1-1/2 scope center blank when in operation. If you have two targets in very close to the minimum range of the radar and you desire to obtain bearings on each one separately by placing center expand on, the targets will move outward from center of scope and permit better definition.
3.	Pulse rate acceptance:	57 to 1000 PPS.
4.	Range accuracy:	Within 1 percent (master radar governs).
5.	Bearing accuracy:	2.2. (master radar governs).

Following is a list of the operator's controls, their purpose, and the correct procedure for turning the gear ON and OFF, plus a few operating techniques. As you know, CIC has to be dark at all times for you to see the pictures on the scopes. To save yourself a lot of time, MAKE it a point NOW to learn the position and purpose of each control. Practice with the gear, if possible, using this checkoff list. If the gear is not available, look at figure 7-3 and learn the position and purpose of the various controls. You should know the controls and their functions so well that, even when blindfolded, you can call out the controls and what they do.

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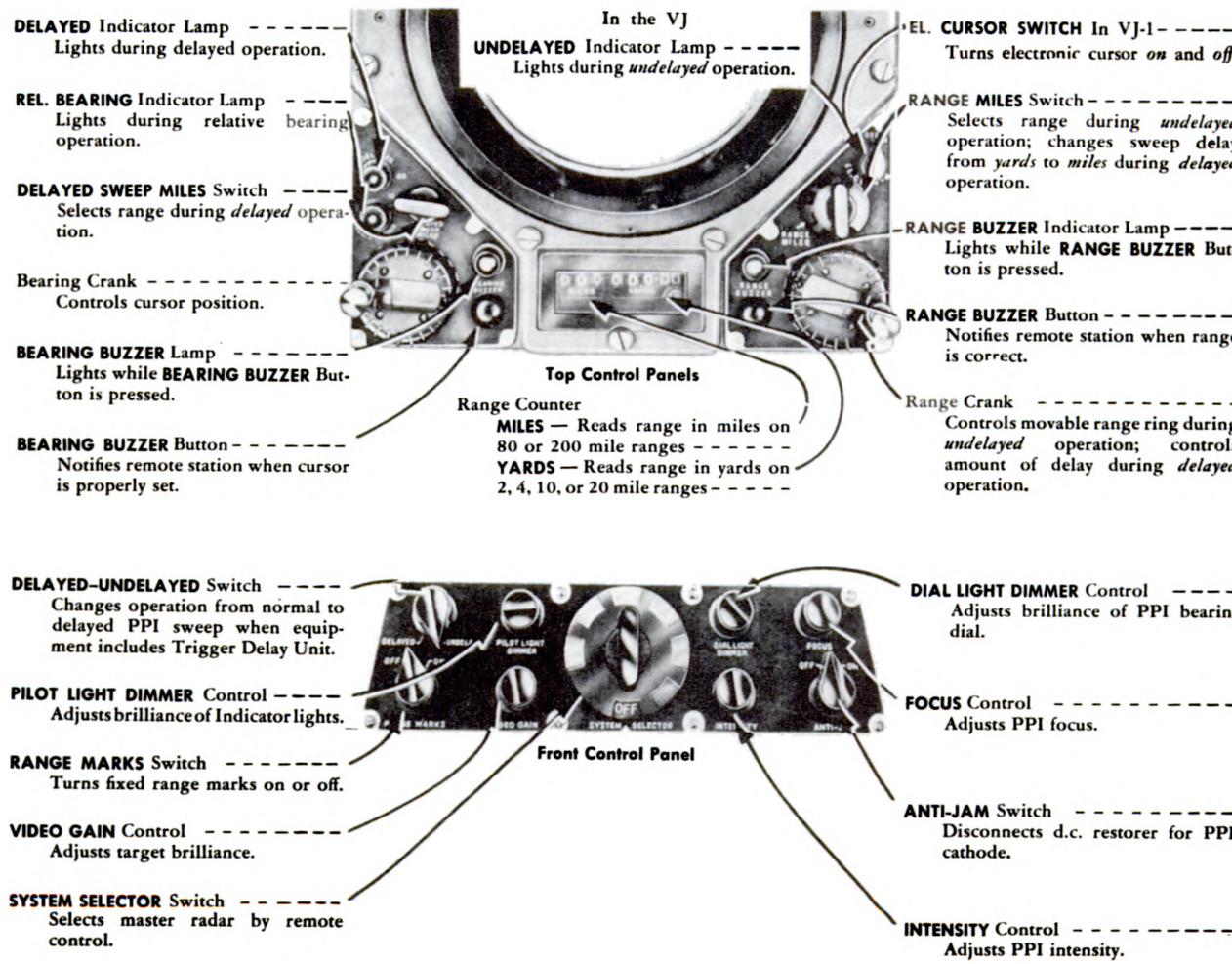
DELAYED Indicator Lamp
Lights during delayed operation.
REL. BEARING Indicator Lamp
Lights during relative bearing operation.
DELAYED SWEEP MILES Switch
Selects range during *delayed* operation.
Bearing Crank
Controls cursor position.
BEARING BUZZER Lamp
Lights while **BEARING BUZZER** Button is pressed.
BEARING BUZZER Button
Notifies remote station when cursor is properly set.
In the VJ
UNDELAYED Indicator Lamp
Lights during *undelayed* operation.
Top Control Panels
Range Counter
MILES — Reads range in miles on 80 or 200 mile ranges
YARDS — Reads range in yards on 2, 4, 10, or 20 mile ranges
EL. CURSOR SWITCH In VJ-1
Turns electronic cursor *on* and *off*.
RANGE MILES Switch
Selects range during *undelayed* operation; changes sweep delay from *yards* to *miles* during *delayed* operation.
RANGE BUZZER Indicator Lamp
Lights while **RANGE BUZZER** Button is pressed.
RANGE BUZZER Button
Notifies remote station when range is correct.
Range Crank
Controls movable range ring during *undelayed* operation; controls amount of delay during *delayed* operation.
DELAYED-UNDELAYED Switch
Changes operation from normal to delayed PPI sweep when equipment includes Trigger Delay Unit.
PILOT LIGHT DIMMER Control
Adjusts brilliance of Indicator lights.
RANGE MARKS Switch
Turns fixed range marks on or off.
VIDEO GAIN Control
Adjusts target brilliance.
SYSTEM SELECTOR Switch
Selects master radar by remote control.
Front Control Panel
DIAL LIGHT DIMMER Control
Adjusts brilliance of PPI bearing dial.
FOCUS Control
Adjusts PPI focus.
ANTI-JAM Switch
Disconnects d.c. restorer for PPI cathode.
INTENSITY Control
Adjusts PPI intensity.

Figure 7-3.—Model VJ remote indicator.

Operator Controls:

ON-STAND-OFF—Main power switch for entire VJ equipment.

BATTLE SHORT switch—Shorts out interlocks.

RANGE SELECTOR switch—Selects range or transfers range control to indicator unit.

DELAYED SWEEP MILES switch—Selects range during delayed operation.

BEARING crank—Controls bearing cursor position.

BEARING BUZZER button—Notifies remote station when cursor is properly set.

RANGE MILES switch—Selects range during undelayed operation. Changes sweep delay from yards to miles during delayed operation.

RANGE BUZZER button—Notifies remote station when range is correct.

RANGE crank—Controls movable range ring during undelayed operation. Controls amount of delay during delayed operation.

DELAYED-UNDELAYED switch—Changes operation from normal to delayed PPI sweep when equipment includes trigger delay unit.

PILOT LIGHT DIMMER—Adjusts brilliance of indicator lights.

RANGE MARKS switch—Turns fixed range marks ON and OFF.

VIDEO gain control—Adjusts target brilliance.

SYSTEM SELECTOR switch—Selects master radar by remote control.

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DIAL LIGHT DIMMER control—Adjusts brilliance of PPI bearing dial.
FOCUS control—Adjusts PPI focus.
ANTIJAM switch—Disconnects DC restorer for PPI cathode.
INTENSITY control—Adjusts PPI intensity.

Turnon Procedure:

1. Prechecks:
   a. Driver unit:
      BATTLE SHORT switch—Turn to OFF.
      ON-STAND-OFF switch—Switch to STANDBY.
      RANGE SELECTOR switch—Turn fully clockwise until REMOTE shows in RANGE MILES window.
   b. Indicator (top panel):
      RANGE MILES switch—Set to desired range.
   c. Indicator (front panel):
      DELAYED-UNDELAYED switch—Switch to UNDELAYED.
      RANGE MARKS switch—Turn OFF.
      VIDEO gain control—Turn fully CCW.
      INTENSITY control—Turn fully CCW.
      ANTIJAM switch—Switch to OFF.
2. Placing equipment in undelayed operation:
   a. Driver unit:
      ON-STANDBY-OFF switch—Switch to ON.
   b. Indicator (top panel):
      RANGE MILES switch—Switch to desired position.
   c. Indicator (front panel):
      SYSTEM SELECTOR switch—Select desired radar.
      INTENSITY control—Turn CW for desired brilliance of trace on PPI.
      FOCUS control—Adjust for maximum sweep sharpness.
      VIDEO gain control—Advance for best picture contrast of targets on PPI.
      RANGE MARKS switch—Switch to ON if range marks are needed.
      PILOT LIGHT DIMMER and DIAL LIGHT DIMMER—Adjust for desired illumination.
3. Placing equipment in delayed sweep operation.
   a. Indicator (front panel):
      DELAYED - UNDELAYED switch—Switch to DELAYED.
   b. Indicator (top panel):
      RANGE MILES switch—Set to 20 miles for reading delay in miles.
      RANGE crank—Turn for desired delay. (Read delay in miles or yards on range counters.)
      DELAYED SWEEP MILES switch—Set on desired range, either 10 or 20 miles.

Turnoff Procedure:

1. Indicator unit—Use precheck procedures; also turn system SELECTOR switch to OFF.
2. Driver unit—Turn ON-STANDBY-OFF switch to OFF.

Operating Techniques:

1. Target ranging:
   a. In undelayed operation—A movable range ring will appear at some point along the sweep.
      (1) Determining range—Turn range crank until ring bisects selected target. Read range on range counters in miles or yards.
      (2) Range buzzer button—Press this button to notify remote stations when range is correct.
   b. In delayed operation—Movable range ring determines amount of delay in delayed operation.
      (1) Range marks—Turn range marks switch to ON. Four concentric range markers should appear on the PPI, if sweep is rotating.
      (2) Separation of range marks—Distance between range marks equals one-fourth the setting of the range miles switch.
      (3) Estimating range—Interpolate, using range marks, and add this total to the range on the range counters.
      (4) Range buzzer button—Not used in delayed operation.
2. Determining target bearing—Turn bearing crank until cursor bisects target.
   a. True bearing—Will be indicated when cursor bisects target, and relative bearing indicator lamp is not glowing.
   b. Relative bearing—Will be indicated when relative bearing indicator lamp is glowing.
   c. Bearing buzzer—Press to notify remote stations when cursor is properly set.
3. ANTIJAM—The ANTIJAM switch will be left in OFF position except when jamming or interference occurs.

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NOTE.—Remember this when operating any piece of equipment: Range cranks can be turned clockwise and counterclockwise only so far and then they will hit the stops. Any further turning will either break the gear or cable connecting the gear or ruin range calibration; in either case it means much work and expense to replace or repair.

OFF-CENTER PPI

PPI's with the off-centering feature are usually used as part of the shipboard airborne early warning presentation, in which the radar display of an airborne radar is transmitted by a radio link to a surface ship. By means of off-centering, the AEW radar picture can be displayed as if the airborne radar were at the center of the ship's PPI. By continually changing the amount of off-centering to conform with the relative movement of the AEW plane, the presentation can be maintained as though ship-centered.

All the more modern PPI's have been provided with the off-centering feature. In addition to the off-centering feature, the modern PPI's have such valuable features as a roving cursor, strobe, and rubber range scales.

The standard PPI-scope presentation uses what is called a radial sweep pivoting about the center of the CRT, resulting in a map-like picture of the area covered by the radar beam. (See fig. 7-4, part A.) A relatively long persistence screen is used so that targets remain visible until the sweep passes again.

In the off-centered presentation (a variation of the PPI), the origin of the radar sweep which normally coincides with the physical center of the face of the CRT is displaced or moved away from that position toward the edge of the indicator. (See part B of fig. 7-4.) This allows the viewer to place any area of particular interest in the entire radar picture in the center of the scope for a close look. In addition to this repositioning feature, it is possible to magnify the area of interest by reducing the range scale. (See fig. 7-4, part C.) The series of events shown in figure 7-4 may be likened to the minute examination of a large-area chart with a strong magnifying glass. A point of particular importance can be looked at with no appreciable degree of distortion, thus allowing the operator to plot targets directly on the face of the indicator without error. This ability has been applied to great advantage in the air control situation, where the off-centered presentation is used almost entirely.

To obtain bearing of targets when in off-center position, an electronic bearing cursor is provided. This originates at sweep origin and is rotated by a bearing crank. Bearing in degrees is read on a set of counters similar to range units. On some repeaters, when the electronic cursor is turned on, video information is cut off.

The range strobe will be visible as a bright spot on the cursor line, solving for range and bearing of target at the same time.

A reflection plotter is provided on all repeaters as standard accessory to eliminate parallax errors in plotting.

FLOATING CURSOR PPI

The floating (or roving) cursor PPI is an improved off-center type of repeater. It is usually a 10-inch high-resolution PPI. Substitution of the 10-inch scope for the 12-inch scope as used in the VK has improved definition and resolution. It is used to repeat all search radars. It can also be used to display AEW terminal information. The range scale is continuously variable (4 to 200 miles), therefore the name "rubber range."

The electronic cursor may be made to start on the radar sweep or on any other selected

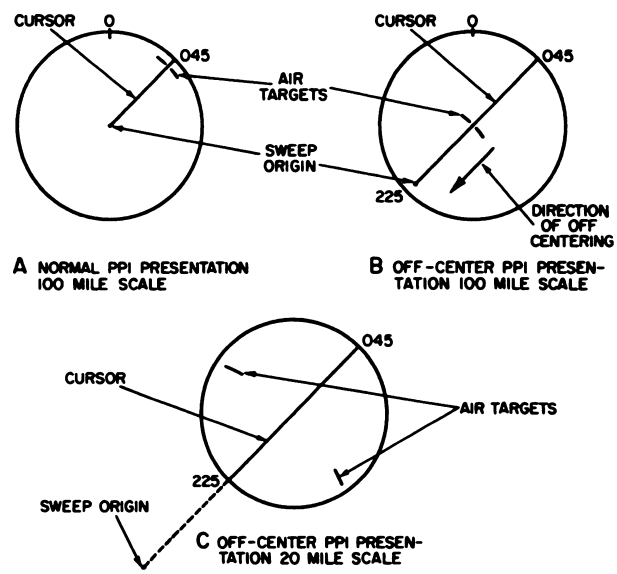

Figure 7-4.—Off-center PPI presentations.

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point on the PPI—for example, the formation center or target reference point.

The repeaters equipped with such special features as the off-center and/or floating cursor PPI's are usually equipped with DRA. Dead reckoning analyzer input can be introduced to automatically off-center sweep in accordance with course and speed of own ship, thus changing the plot from relative to geographic.

VK SERIES OF REMOTE INDICATORS

Three of the VK series of indicators will be considered here: The VK, VK-2, and VK-4. During the lifetime of this book, one or more of these may be replaced by more modern models. However, since all repeaters are basically the same, this information will be of help in understanding the newer ones. The material included is designed not only to describe the functions and purpose of the VK, VK-2, and VK-4 repeaters but to serve as a detailed guide for the proper operating procedures to be employed. You will notice that the VK-2 and -4 are discussed as one indicator since they are identical from an operational standpoint. (Another, the VK-5, not described here, is a modified VK-4.)

VK RADAR REPEATER

General Characteristics

The VK radar repeater is a remote indicator used with shipboard radars to display range and azimuth information. When operated with the AEW system, it is used with a tracking indicator as a final repeater to display radar information from an airborne early warning radar. The pulse repetition rate acceptance is 57-2000 PPS, allowing it to be used with any present-day radars. The antenna and trace rotation speed is 0-60 RPM. Range accuracy is as follows: from 0-18,000 to 100,000 yards, plus or minus 100 yards; from 18,000 to 100,000 yards, plus or minus 1 percent; 0-200 miles, plus or minus 5 percent. The bearing accuracy is within 2.2°. The indicator is a 12-inch CRT with range scale selection in the centered position of 4, 10, 20, 40, 80, and 200 miles. A special feature of this repeater, which the VJ does not have, is the off-centered PPI with the same range scale selection as the centered position. This manual off-centering feature allows any target within 80 miles to be centered on the scope. Another special feature is the DRA off-centering. Information from the ship's DRA may be fed to the repeater. This will cancel own ship's motion, and show all targets, including own ship, moving on their true courses.

VK-2 AND VK-4 RADAR REPEATERS

The VK-2 and VK-4 are radar repeaters with the same general characteristics as the VK. The special features of these repeaters are the same as the VK with the exception of the sector sharing feature, which allows alternate display of electronic cursor and video in any desired sector. Center bearing of the sector is determined by the electronic cursor. Figure 7-5 will acquaint you with the location of the operator controls. Functions of these controls are as follows:

Operator Controls (front panel)—Not shown in illustration:

- D-C RESTORER—Normally left in ON position. Under certain unfavorable circumstances, such as in the presence of jamming signals, turning the D-C restorer OFF may improve the quality of the display.
- OFF-CENTER switch—Three-position switch. Normal off-centered switch on top panel must be in off-centered position.
- MANUAL—Allows manual off-centering of a shipboard radar display by use of east-west and north-south off-centering controls on top panel.
- DRA—Allows manual off-centering of display when using the DRA input.
- AEW—Allows manual off-centering of airborne early warning radar information when repeater is used as a final indicator.
- RADAR SELECTOR—Selects the master radar to be used.

Operator Controls (top panel) shown in fig. 7-5:

- POWER ON-OFF switch—Turns on power.
- NORMAL/OFF-CENTER switch—Allows selection of a centered or off-centered presentation.
- RANGE SELECTOR—Two selector switches:
  - NORMAL—4, 10, 20, 40, 80, 200 miles.
  - OFF-CENTER—4, 10, 20, 40, 80, 200 miles.
- DIAL DIMMER—Controls the lighting of the various dials.
- FOCUS—Controls sweep focus.

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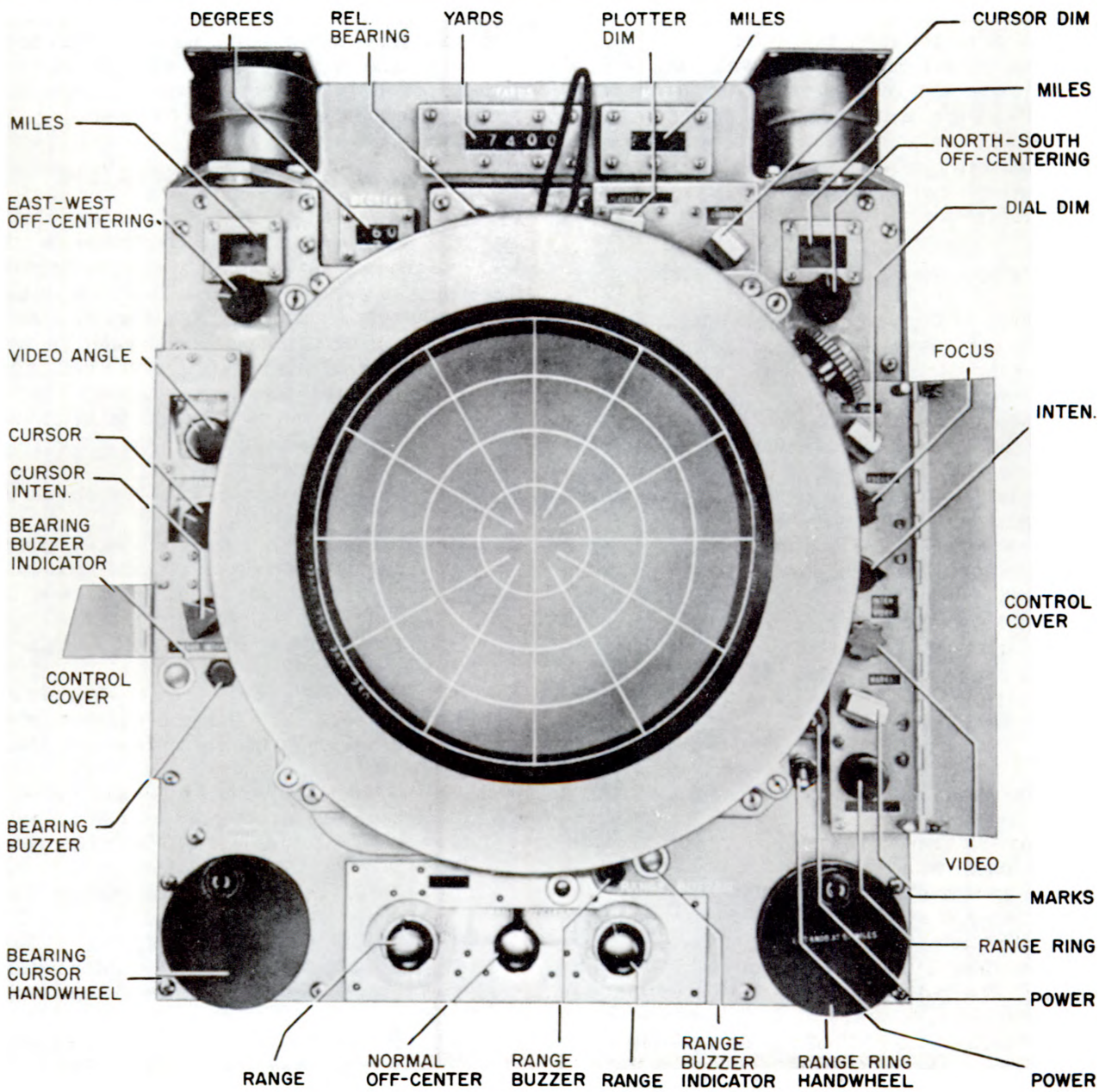

Figure 7-5.—VK-4 remote indicator.

INTENSITY—Controls the basic intensity of the sweep.

VIDEO gain—Controls the intensity of the display of received radar echoes.

RANGE MARKS INTENSITY—Controls the intensity of the range markers generated by the sweep.

RANGE RING INTENSITY—Controls the intensity of the range ring marker (strobe).

BEARING CURSOR crank—Rotates the mechanical and electronic cursors. The mechanical and electronic cursors parallel each other at all times.

RANGE RING crank—Positions the range ring (strobe) along the electronic cursor. The corresponding range may be read in yards or miles on the range counter.

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RANGE and BEARING BUZZERS—When the repeater is used to relay information to a remote location, the buzzers are used to signal the instant that the information relayed is correct.

CURSOR—Three-position switch:
OFF—Electronic cursor off.
NORMAL—Electronic cursor positioned at origin of sweep.
CENTER—Electronic cursor origin at center of CRT screen.

SECTOR SHARING—Center of sector to be displayed is determined by position of electronic cursor.

Video angle
0°—Cursor only—no video.
20°—Video presented through 20°-10° either side of electronic cursor.
90°—Video presented through 90°-45° either side of electronic cursor.
180°—Video presented through 180°-90° either side of electronic cursor.

CURSOR INTENSITY—Varies the intensity of the electronic cursor.

CURSOR DIMMER—Controls the brilliance of lighting of the cursor dial and bearing ring.

EAST-WEST OFF-CENTER—Presentation may be off-centered east or west.

NORTH-SOUTH OFF-CENTER—Presentation may be off-centered north or south.

Turnon Procedure:

Prechecks—Failure to perform prechecks before turning on the power may result in damage to the CRT.

VIDEO gain—Turn fully CCW.
RANGE MARKER—Turn fully CCW.
RANGE RING (strobe)—Turn fully CCW.
INTENSITY—Turn fully CCW.
CURSOR INTENSITY—Turn fully CCW.
POWER switch—ON.
BATTLE SHORT—OFF.
RADAR SELECTOR—Select radar to be used.
NORMAL/OFF-CENTER—NORMAL position.
INTENSITY—Advance slowly until trace becomes visible.
VIDEO gain—Advance until desired video intensity is obtained.
CURSOR DIMMER—Adjust for desired lighting of bearing ring.
DIAL DIMMER—Adjust for desired lighting of dials.
PLOTTER DIMMER—Adjust for desired lighting of reflection plotter.

Turnoff Procedure:

VIDEO gain—Turn fully CCW.
RANGE MARKERS—Turn fully CCW.
RANGE RING—Turn fully CCW.
INTENSITY—Turn fully CCW.
CURSOR INTENSITY—Turn fully CCW.
POWER—OFF.

Operating Techniques:

1. Determining target bearing:
   Mechanical cursor—In the centered presentation, target bearings may be found by bisecting the target with the mechanical cursor and reading the bearing with reference to the bearing ring. In the off-centered presentation, it is necessary to use the electronic cursor for accurate bearing determination.
   Electronic cursor—Obtained from cursor selector. Adjust video angle as necessary. The greater the amount of off-centering the smaller the video angle needed.
   Cursor in normal position—Bisect target with electronic cursor by rotating cursor crank. Read target bearing with reference to bearing ring or bearing from origin of sweep.
2. Determining target range—Determine target's bearing with electronic cursor. Turn range ring crank until range ring (strobe) bisects target. Read range from range counter.
   Manual off-centering display—Place the manual off-center switch in the off-center position. Select an appropriate range in the off-centered presentation. Turn the north-south and east-west off-centering controls until desired off-centering is obtained.
   Manual off-centering of a particular target—Place the range ring over target. Turn off-center range ring to desired position. The target will remain under the range ring during the off-centering operation.

At this point it is again mentioned that the type of equipment already discussed may not be aboard your ship or station. But operating a repeater may be compared with operating a car: Once you have learned to drive one model, you can drive any car with little difficulty after you have mastered the location of the controls and their purposes. So it is with the repeater—most

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newer models of repeaters will consist only of better circuitry and design features. Some will have larger CRT's and better definition capabilities, longer ranges, controls placed in different locations, etc.

REMOTE INDICATORS AN/SPA-8, 8A, 9

The AN/SPA-8, 8A, and 9 are general purpose PPI's for ship or submarine use. They can be used as master or remote PPI indicators, as relay search repeat indicators, or as radar relay search tracking indicators. They are frequently used as tracking and repeat indicators with Radio Receiving Set AN/ SRR-4, which is the shipboard section of the AEW (airborne early warning) system.

This equipment features (1) continuous range sweep variation without loss of target, (2) time sharing of the electronic cursor and range sweeps or the strobe and range sweeps, and (3) sweep and cursor off-centering, which make target identification possible without geographic distortion. These indicators incorporate the same features. The AN/SPA-9 is used for tracking while the AN/SPA-8 cannot be used for tracking but is used for a repeater (sometimes called a slave). The AN/SPA-8A is a single indicator used either for tracking purposes or as a slave.

The AN/SPA-8A

The AN/SPA-8A repeater (fig. 7-6) may be regarded as a much improved VK-4 equipment. Following is a detailed description of the operating functions and controls.

General Characteristics:

1. Purpose:
   a. Shipboard—A remote indicator used with shipboard radars to display range and bearing information.
   b. AEW system—Used in conjunction with another AN/SPA-8A, or AN/SPA-8, or AN/SPA-9 to display radar information from an airborne early warning radar. When used with another AN/-SPA-8A, either may be used as a tracking indicator and the other as a final (repeat) indicator. When the AN/SPA-8A is employed with the AN/SPA-9, it is used as a final (repeat) indicator. When the AN/SPA-8A is employed with the AN/SPA-8,it is used as a tracking indicator.
2. Pulse repetition frequency acceptance—60 to 3000 PPS.
3. Antenna and trace rotation speed—from 0 to 40 RPM.
4. Range accuracy—300-10,000 yards is plus or minus 100 yards; 5 to 36 miles, 1 percent; 36 to 300 miles, 2 percent.
5. Bearing accuracy—Within 2°.
6. Indicator—Good definition on 10-1/2-inch CRT.
7. Range scale:
   Center PPI—Rubber range, 4 to 300 miles, continuously variable.
   Off-center PPI—Rubber range, 4 to 300 miles, continuously variable.

Special Features:

1. Manual off-centering—Any target within 250 miles may be centered on the scope.
2. DRA off-centering—Information from the ship's DRA may be fed to the repeater. This will cancel own ship's motion, and show all targets, including own ship, moving on their true courses.
3. Electronics cursor and range strobe—Provided with a centered or off-centered electronic cursor and range strobe. Origin of off-centered cursor and strobe may be controlled independently from sweep by tracking cranks.
4. Range rings—A choice of six different scale spacings between range rings.
5. Tracking cranks—Used to position origin of strobe or electronic cursor. The tracking cranks may be locked so that the repeater can be used as a final (repeat) AEW indicator.

Operator Controls (front panel) (lower half of fig. 7-6):

1.6 AMP. SLO BLO FUSE—Protects unrelated filament transformer.

D-C RESTORER—Normally left in ON position. Under certain adverse circumstances, such as in the presence of jamming signals, depressing the D-C restorer switch may improve the quality of the display.

CENTER/OFF-CENTER switch—Allows selection of centered or off-centered presentation.

DRA synchro—Enables use of information from ship's DRA for off-centering the display, provided that the center/off-center switch is in the off-center position.

RADAR SELECTOR—Selects the master radar to be used.

FUNCTION CONTROL switch—A 7-position control which changes the operation of the

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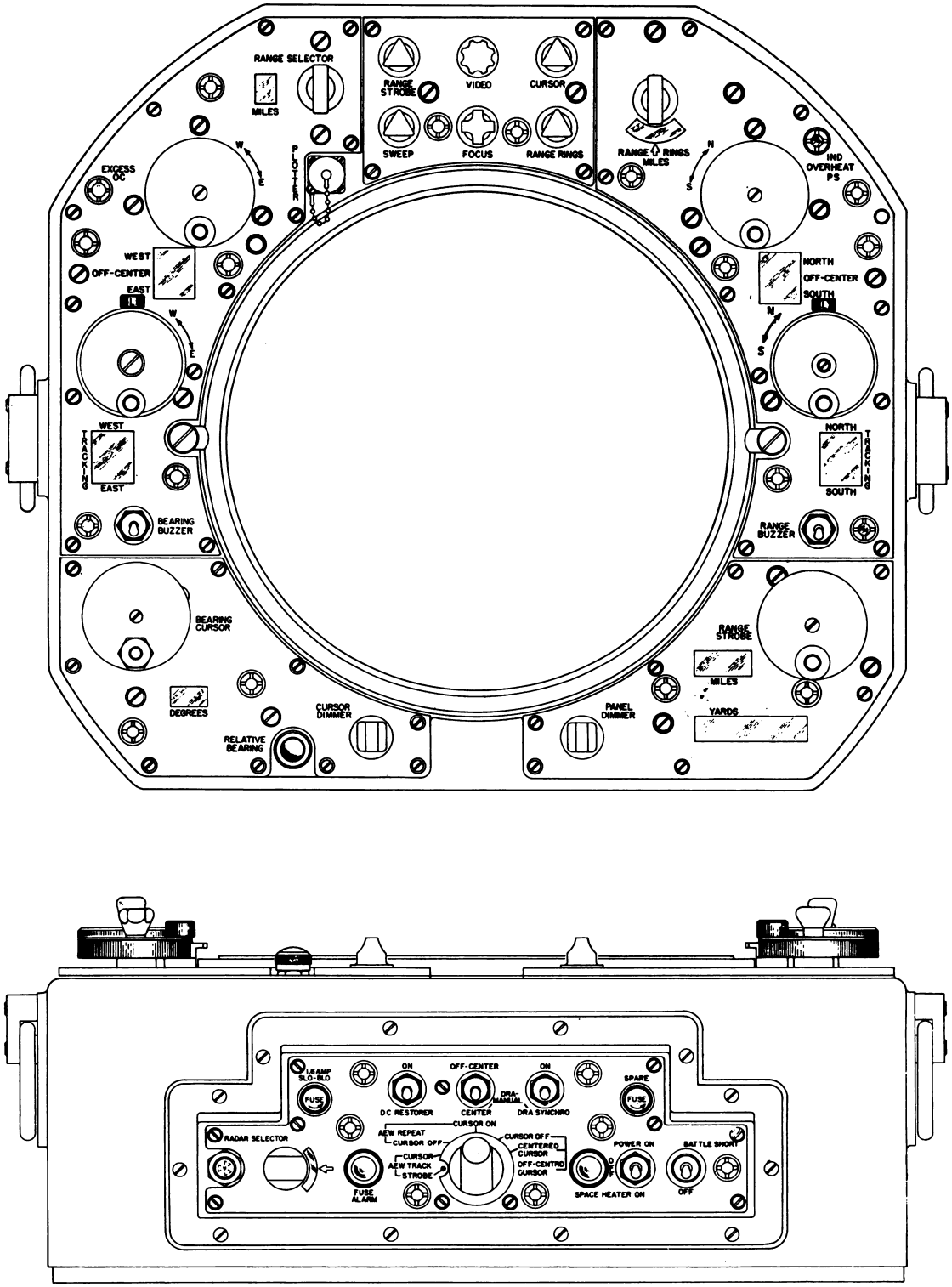

Figure 7-6.—AN/SPA-8A.

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indicator to a tracking, a final, or a general-purpose PPI.

1. AEW TRACK STROBE—The indicator is used as an AEW tracking indicator. A tracking strobe is provided and is normally maintained on your own ship by use of the tracking crank.
2. AEW TRACK CURSOR—The indicator is used as an AEW tracking indicator. An electronic cursor is provided. The origin of the electronic cursor is normally maintained on our own ship by use of the tracking cranks. Range and bearing information may be obtained on a target by use of the bearing cursor crank, range strobe, and range strobe crank.
3. AEW REPEAT CURSOR OFF—The indicator is used as an AEW final indicator without an electronic cursor. Off-centering information is received from the tracking indicator for displaying an "own ship" centered presentation.
4. AEW REPEAT CURSOR ON—The indicator is used as an AEW final indicator with an electronic cursor. Off-centering information is received from the tracking indicator for displaying an "own ship" centered presentation. Range and bearing information may be obtained on targets by use of the bearing cursor crank, range strobe, and range strobe crank.
5. CURSOR OFF—The indicator is used as a general-purpose PPI without an electronic cursor.
6. CENTERED CURSOR—The indicator is used as a general-purpose PPI with a centered electronic cursor. Range and bearing information may be obtained by use of bearing cursor crank, range strobe, and range strobe crank.
7. OFF-CENTER CURSOR—The indicator is used as a general-purpose PPI with an off-centered electronic cursor. The origin of the electronic cursor may be positioned on any target by use of the tracking cranks. Range and bearing information from this target may be obtained on any target by use of the bearing cursor crank, range strobe, and range strobe crank.

POWER ON-OFF SPACE HEATER ON switch—A 3-position switch which turns on power for the entire unit or for the heaters only.

BATTLE SHORT switch—Shorts out interlock switches when turned ON (up) and red warning light to right of switch goes on. This switch is provided for use under emergency battle conditions, or during equipment servicing only.

Operator Controls (top panel):

PANEL DIMMER—Controls the lighting of all counters and dials.

CURSOR DIMMER—Controls the lighting of the azimuth scale which encircles the display.

BEARING CURSOR crank—Controls the azimuth (bearing) setting of both the electronic and mechanical cursors.

RANGE STROBE crank—Controls the setting of the range strobe. The range strobe is a small, bright spot which moves along the sweep or electronic cursor (depending upon selection of the function control switch) and measures distance from the origin of the sweep or electronic cursor.

RANGE and BEARING BUZZERS—When equipment is being used to relay information to a remote location, the buzzers are used to signal the instant that the information relayed is correct.

TRACKING cranks—Control the position of the tracking strobe or the origin of the electronic cursor on the PPI; one crank in north-south direction, and one crank in east-west direction.

OFF-CENTER cranks—Control the position of the origin of sweep. Center/off-center switch must be in off-center position. One crank off-centers in a north-south direction, and the other crank in an east-west direction.

RANGE RING MILES—Provides a selection of six different scale spacings between range rings. The range rings are generated by the rotation of range marks on the video sweep. (Range marks may be made to appear on the centered or off-centered cursor.)

RANGE RINGS—Control range ring intensity.

RANGE STROBE—Controls range strobe intensity.

VIDEO—Controls video intensity.

CURSOR—Controls sweep intensity. There is some interaction between the sweep and cursor intensity controls, and therefore the sweep intensity should be adjusted before the cursor intensity.

FOCUS—Controls the clearness of the sweep.

RANGE SELECTOR—Allows selection of any desired display range between 4 and 300

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miles. Range per radius of PPI is shown on a miles counter next to the range selector.

RELATIVE BEARING light—Provides warning if directional information (north stabilization) from ship's gyro fails. If light comes on, all targets will appear relative to the ship's course.

EXCESS OFF-CENTER light—Provides warning when the display is showing incorrect range and/or bearing readings due to certain combinations of sweep range and off-centering settings.

IND-OVERHEAT-PS lights—Provide warning when the power supply or indicator overheats.

PLOTTER—An electrical jack used to supply power to the reflection plotter, if used.

Turnon Procedure:

Prechecks—Failure to perform prechecks before turning on power may result in damage to the CRT.

SWEEP INTENSITY—Turn fully CCW.

CURSOR INTENSITY—Turn fully CCW.

VIDEO gain—Turn fully CCW.

Turn on—Adjust controls as follows:

POWER—Turn on and wait 45 seconds.

CURSOR and PANEL DIMMERS—Adjust for desired illumination.

RADAR SELECTOR—Turn to desired position.

DC RESTORER—ON.

BATTLE SHORT—OFF.

CENTER/OFF-CENTER—CENTER.

DRA SYNCHRO—Down (off).

RANGE SELECTOR—Set to any desired position.

SWEEP INTENSITY—Advance slowly until faint trace appears.

FOCUS—Adjust for sharp definition of sweep.

SWEEP INTENSITY—Decrease intensity until trace (sweep) is barely visible.

VIDEO gain—Advance until desired intensity of signal is obtained.

RANGE RINGS selector—Set to any desired position.

RANGE RINGS INTENSITY—Adjust for desired intensity.

FUNCTION CONTROL switch—Place switch in the position which provides for the type of operation desired.

Turnoff Procedure:

INTENSITY controls—Turn all intensity controls fully counterclockwise.

RADAR SELECTOR—Turn to OFF.

FUNCTION CONTROL switch—Place switch in the cursor off, centered cursor, or the off-centered cursor position unless there is some definite reason for desiring to keep the AEW off-centering channel synchronized to some other indicator. This is necessary so as to deenergize the AEW synchro when the indicator is not in use.

POWER switch—Turn switch to heater position.

Heaters normally should be left on when equipment is not in operation. If it is desired to secure heaters prior to entry into the cabinet, place switch in OFF position.

Operating Techniques:

1. General—The AN/SPA-8A is capable of performing several basic operations. In addition, by combining the indicator's basic functions, there is an almost unlimited variety of operations that may be performed. Some of these combined operations will be discussed in a subsequent section.
2. Search—Turn on and carefully adjust the equipment as previously outlined. Identify and track all contacts on the scope. Maintain careful watch for new contacts.
3. Off-centered display:

   RANGE SELECTOR—Set to desired scale.

   CENTER/OFF-CENTER switch—Off-center position.

   OFF-CENTER cranks—Turn the north-south cranks until desired off-centering is obtained.
4. Determine target range and bearing from origin of video sweep.

   FUNCTION CONTROL switch—Turn to centered cursor position.

   CURSOR INTENSITY—Advance cursor intensity until cursor appears on the scope.

   RANGE STROBE—Adjust range strobe intensity until range strobe appears on the cursor as a bright spot.

   Determine bearing—Turn bearing cursor crank until the electronic cursor bisects the target echo. Read bearing in degrees on bearing counter. Bearing obtained will be a true bearing, unless the relative bearing indicator lamp is lighted, in which case the bearing will be relative to ship's head.

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5. Expanded presentation of a particular target:
   a. Place range strobe on the target—Turn function control switch to centered cursor position, and place the electronic cursor and range strobe on the target as when determining bearing and range.
   b. Manually off-center the display by:
      (1) Turning off-center switch ON.
      (2) Turning the north-south and east-west off-centering cranks until the range strobe is located near the center of the scope.
   c. Expand the display—Turn the range selector so it will provide as large a display (small number of miles) as is desired.
6. AEW tracking indicator—Tracking may be accomplished with either the tracking strobe or the origin of the electronic cursor. Tracking with the strobe is more accurate, but tracking with the cursor will allow the operator to determine range and bearing from own ship to any other target while tracking own ship.
   a. Tracking with tracking strobe:
      (1) FUNCTIONAL CONTROL switch—Set to the AEW track strobe position.
      (2) CURSOR INTENSITY—Adjust until the tracking strobe appears as a sharp, bright dot.
      (3) Identify own ship—Own ship's echo may be identified by:
         (a) Plotting the reciprocal of the known or estimated position of the AEW plane from the center of the sweep:
         or
         (b) Observing IFF or beacon replies from own ship.
      (4) Track own ship—Align tracking strobe with own ship's echo by turning north-south and east-west tracking cranks.

AN/SPA-8 AND -9 REMOTE INDICATORS

The AN/SPA-8 and AN/SPA-9 repeaters are almost identical to the AN/SPA-8A. In fact the -8A is a combined -8 and -9. The former differs in that it cannot be used as an AEW tracking indicator nor does it have an off-centered cursor. The latter differs in that it cannot be used as an AEW final indicator nor can it be off-centered by DRA.

THE AN/SPA-33

The AN/SPA-33 is a general purpose plan position indicator with practically the same controls as the AN/ SPA-8 or 8A. By means of a front panel function control switch, it can be used as an ordinary PPI, as an AEW tracking indicator, or as an AEW repeat (final) indicator.

ADDITIONAL INDICATORS

Other indicators bearing AN/SPA-( ) designations can be described briefly as modifications of those discussed previously. For example, the AN/SPA-23 contains a larger CRT, while the AN/SPA-25 is a prototype indicator, which uses transistors instead of vacuum tubes.

The AN/SPA-22 is built into a console, which is arranged for best serving intercept operations. The AN/SPA-26 is a group of indicators. The AN/SPA-31 is a RHI (range height indicator), while the AN/SPA-32 is a PPI (plan position indicator) for use with the AN/SPS-26 search radar. The AN/SPA-34 is a PPI built into a console.

RANGE-HEIGHT INDICATOR (RHI)

You remember from previous chapters that the RHI is used for determining the range and height (altitude) of air targets. The presentation is so arranged that slant range is measured along the horizontal axis and height along the vertical axis. (See fig. 7-7.) It usually will feature vertical electronic range markers and a movable vertical electronic height line. Targets will appear as vertical pips which are bisected with the height line for altitude measurement.

VL-1 REMOTE INDICATOR

The VL-1 is a range-height indicator used to display radar information from any vertical scanning height finder radar. These indicators usually are associated with the AN/SPS-8 radar, and will be considered together at this point, insofar as operating procedure is concerned. (Any vertical scan radar may be substituted for the AN/SPS-8.)

General characteristics of the VL are as follows:

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The model VL series of RHI-scopes are designed to read target range and altitude directly. The indicator is of the RHI type with a 12-inch display tube, but only a 10-inch viewing surface is used to present a vertical sector scanned by the radar. It can cover from 5° below the horizontal to 90° above. An expand control allows the 11° sector normally scanned by the radar to be expanded on the scope to about four times its normal size.

Range scales available are 20, 40, 80, or 200 miles with radar centered, or a 20- to 40-mile delayed range scale.

An electronically written height cursor, curved to make up for earth curvature, is used to measure altitude directly by positioning cursor on target.

An electronically written position angle cursor may be switched on to read target position angle, or to transmit position angle into the target designation system by means of synchros.

Since the VL indicator has no azimuth information, an azimuth sector gating feature is provided to ensure the VL is measuring altitude on the same target as the main radar is tracking. A 10° or 30° sector is provided, as well as 360° area coverage, with the center bearing of the sector chosen at the VL-1 or the PPI, depending on the position of the SECTOR CONTROL switch at the VL-1.

The pulse rate acceptance is 60 to 3000 PPS.

The range accuracy is plus or minus 1 percent of total scale. Altitude accuracy depends on the parent radar.

The controls and their functions, turnon procedure, turnoff procedure, and the operating techniques are as follows. (The controls are shown in fig. 7-8.)

Controls:

POWER—Master power switch for entire VL-1.

BATTLE SHORT—Disconnects system's safety interlocks.

DISPLAY selector—Selects any one of three types of presentation:

ANGLE MARK (no video).
HEIGHT LINE.
ANGLE MARK OR VIDEO.

VIDEO SECTOR ANGLE—Selects width of azimuth sector.

The antenna sector display may be 10°, 30°, or 360°.

SECTOR CONTROL—Determines whether sector will be controlled manually or from remote radar PPI.

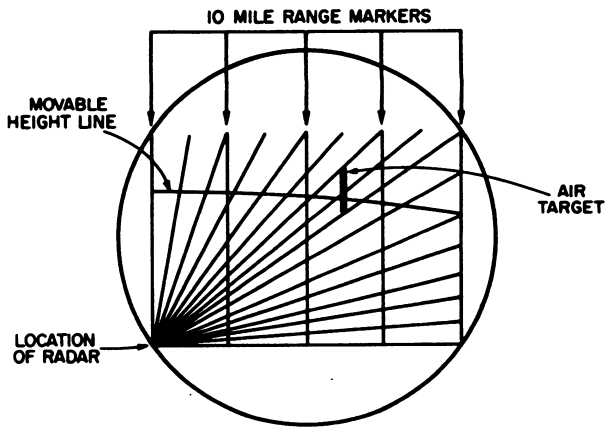

Figure 7-7.—RHI presentation, 40-mile scale.

D-C RESTORER—Suppresses unwanted signals masking smaller targets.

OVERHEATING WARNING LIGHT—Indicates unit is above operating temperature.

FUSE ALARMS—Indicate fuses have blown.

VIDEO gain—Controls over-all intensity of radar signals.

HEIGHT LINE—Controls brilliance of height lines.

FOCUS—Controls sharpness of entire presentation.

DIAL DIMMER—Controls lighting of indicator dial.

ANGLE MARK—Controls intensity of angle mark.

RANGE MARKERS—Control intensity of range markers.

RANGE LINE—Controls intensity of the movable range line.

INTENSITY—Controls intensity of sweep.

ANGLE MARK BUZZER and BUZZER LIGHT—The buzzer sends angle mark information to remote stations. Buzzer light glows when buzzer is operated.

RANGE DELAY—Delays start of sweep from zero to a maximum of 180 miles as indicated on the range delay dial.

SECTOR POSITION—Controls bearing of the center position of the sector gating, when the sector control switch is in the manual position.

HEIGHT EXPANSION—Varies vertical scale of the presentation.

HEIGHT LINE HANDWHEEL—Moves position of height line.

RHI RANGE selector—Selects either normal or delayed RHI presentation.

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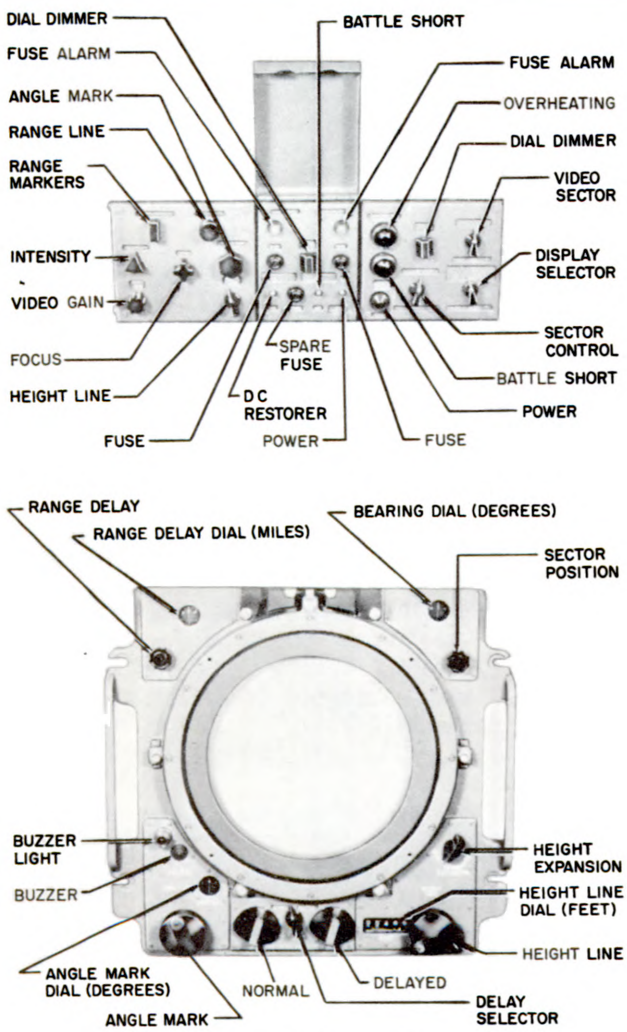

Figure 7-8.—VL-1 remote indicator.

NORMAL—Selects a range scale for normal RHI presentation when RHI range selector is in the normal position.

DELAYED—Selects the range scale for delayed RHI presentation, with the amount of delay fixed by the range delay control setting when the RHI range selector switch is in the delayed position.

Turnon Procedure:

Prechecks—Failure to perform prechecks before turning on the power may result in damage to the CRT. Set controls as follows:

VIDEO gain fully CCW.
RANGE MARKERS fully CCW.
HEIGHT LINE fully CCW.
RANGE LINE fully CCW.
ANGLE MARK fully CCW.
INTENSITY MARK fully CCW.
RHI RANGE selector to NORMAL.
NORMAL to 20.
BATTLE SHORT to OFF.

Turn on :

POWER switch—Turn to ON.

Initial switch positions—Turn the SECTOR CONTROL switch to MANUAL.

Adjusting the trace—Adjust INTENSITY and FOCUS until a barely visible but clear trace appears.

VIDEO Gain—Adjust the video gain control until the desired video intensity is obtained. A reasonable amount of random noise or snow should be reduced for better definition of targets.

RANGE MARKERS—Advance the range markers control until the markers appear on the viewing screen.

RANGE LINE—Adjust the range line control till the range line appears the same as markers.

HEIGHT LINE—Adjust the height line intensity control until the height line appears clearly visible, but observe precautions against excessive brilliance.

D-C RESTORER-ON—To prevent the masking of low altitude and weak targets.

The VL-1 repeater is now ready for operation.

Turnoff Procedure:

Set the following controls to CCW position:
VIDEO gain;
RANGE MARKERS;
HEIGHT LINE;
RANGE LINE;
ANGLE MARK;
INTENSITY;
POWER switch to OFF.

The VL-1 repeater is now secured.

Operating Techniques:

In operating the VL-1, many variables must be taken into account. Height and bearing information will be supplied by a radar such as the AN/SPS-8. The portion of this information to be used may be selected by controls on the VL-1. The variables controllable by the VL-1 are:

SECTOR ANGLE—This angle of 10°, 30°, or 360° is the total amount in degrees of display to be presented on the VL-1. When 10° or 30° sector scanning is used, the position or bearing of the sector to be scanned may be selected by the sector position knob.

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RANGE (NORMAL)—Any of four ranges may be selected and displayed. On normal range, the beginning of the presentation is zero.

RANGE (DELAYED)—Any of four ranges may be selected and displayed. A delay continuously variable from 0 to 180 miles may be added. Thus a range of 20 miles can be displayed from 0 to 20 miles or 180 to 200 miles or any intermediate position as desired. The same holds true for the 40- and 70-mile scales, but on the 140-mile scale the maximum range is limited to a total of 270 miles. The range sweep of the VL-1 prevents complete coverage of the 140-mile range position. Range of only 130 miles is presented when over 140 miles of delay is applied to the 140-mile range. This function begins when the delayed range is at 140 or over.

HEIGHT EXPANSION—A continuous variable to control expansion of the first 20,000 feet of height presentation. This control can vary from a total presentation of 100,000 feet to a 5 to 1 ratio presentation which expands the lower 20,000 feet. This enables the operator to tell the size and composition of a target more easily.

HEIGHT LINE—A control of the height line by which the height may be determined. The height line can be raised or lowered by means of the handwheel control to intersect any target and then the true height of the target above the earth may be read on the counter.

Under the pressures of actual operating conditions, you must be able to "think" with your hands, to adjust and operate and maintain and repair. It is not enough for you to "understand"; you must be a good craftsman—a man who can DO.

Break out the instruction book for the equipment you will be operating and take a look at section 4, titled "Operation". It will give you instructions similar to the information covered here. Use the instructions to practice and learn the correct procedure from the start. Ask questions when in doubt.

Your success as a Radarman depends not only on how well you know your work and how well you do your job. You are rated also on your character, your personality and appearance, your knowledge of the Navy in general. The Navy values men with initiative—the ability and willingness to see a job that needs to be done and to do it without waiting to be told, and to do it well and quickly without a Chief standing behind you to show you. The instruction books for the equipments to be operated by you will help you obtain this success. Don't wait for the Chief to tell you how to operate the equipment.

QUIZ

1. What advantage does the remote indicator have over the console?
2. Any radar repeater requires three types of information from the master radar. What are they?
3. The three types of information are connected to the indicator from the master radar via _____ _____ _____
4. Name three types of radar presentations.
5. Why is it necessary that the remote indicator sweeps be synchronized in azimuth with the antenna of the main radar?
6. Why is it necessary to turn all intensity and gain controls down (CCW) before applying power to an indicator?
7. What is a special feature of the VF repeater?
8. What is the principal disadvantage of the projection PPI?
9. What is a special feature of the VJ repeater?
10. Name a special feature of the VK.
11. Why is it important for you to know the location and function of all controls on the equipment you will operate?
12. What extra precaution should you be aware of while manipulating the range cranks on a repeater?
13. What is a special feature of the VL-1 repeater?
14. Where can you find information on how to operate the radar repeaters you will be using?

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CHAPTER 8

OPERATIONAL TECHNIQUES

INTRODUCTION

In these days of fast aircraft, ships, and submarines, the time element is of such great importance that little remains to be said about the need for TEAMWORK in performing the primary functions of collection, display, evaluation, and dissemination of tactical information.

Every attempt must be made by CIC personnel to carry out their tasks in a minimum of time and with the least effort. It can be seen that the collection, interpretation, and evaluation of information furnished by radar, when used with data provided by other means, would be of value in planning offensive action as well as alerting the force to defense against enemy attack.

Only through proper procedure and teamwork can we hope to become expert in developing a well-organized defense team in CIC.

PERSONNEL FUNCTIONS IN DETECTING AND TRACKING

As a Radarman Third or Second, you may find yourself in charge of a radar gang, especially on a small ship. One of the duties of a leading Radarman is to help the CIC officer assign responsibilities to other men and supervise them in operating surveillance and height-finding radar and associated equipment.

As a petty officer, second or third, you not only tell a man what to do—you show him how, when necessary. When you assign a man to a job as a radar operator, for example, you should be able to operate the radar better than he can. You must be prepared to tell your men and show them how and when to set the various controls of the radar and repeaters in order to get the best performance from the equipment. Also tell them and show them, if necessary, how to tell radar contacts caused by ship, aircraft, and missiles from those caused by natural disturbances.

Success in identifying echo signals depends in large measure upon the skill of the operator. A well-trained operator can pick out on the scope weak echoes that otherwise would go unnoticed. Often he can identify the nature of the target from the echo trace. In addition, he can often determine the approximate course and speed of moving objects. Skill in using the antijam switch and the STC switch located on the radar set control or general control unit will aid in evaluation.

The best way to obtain skill and experience is through practice. When your ship is undergoing exercises, you must remember that you are in training and helping to train others in the gang. It is highly important to simulate actual combat conditions. In the event of conflict, this training will prove extremely valuable.

SEARCH OPERATOR

Before any operation or exercise, make sure the radar is tuned and properly adjusted for searching. Become familiar with the tactical situation so that you may search more effectively in the probable direction of attack. Such tactical information includes:

1. Probable sectors of attack.
2. Type of expected attack.
3. Position of combat air patrol (CAP), AEW, and other friendly aircraft.
4. Expected routes and times of returning strike aircraft.
5. IFF mode of returning strike aircraft, CAP, AEW, and other friendly aircraft.
6. Radar guard assignments and responsibilities.
7. Positions of other task units.
8. Surrounding geographic areas.
9. Weather data that may affect radar results.

The search operator must use the best available scopes. In most cases these will include both an A-scope and a PPI-scope. Since an A-scope is more sensitive than a PPI-scope, long-range targets can often be detected on the A-scope first. Once the contact is established on the PPI, range and bearing can be taken directly from the PPI, while at the same time the target is checked for

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IFF response. IFF cannot be obtained from the A-scope. Immediately upon detection, range and bearing of the target are reported to the summary plot in the case of air contact, and to the DRT plot in case of surface contact. Operators must not stop the antenna without obtaining permission from the CIC watch officer, due to the danger of alerting an ECM-equipped aircraft or ship that it has been detected. On the AN/SPS-8 series of radars, the composition, range, and bearing can be determined without stopping the search radar antenna. The search operator should have no other tasks than detecting and reporting NEW targets.

TRACKING OPERATOR

Upon the report of a target by the search operator, a second operator on a remote PPI, known as the tracking operator, should relieve the search operator of the responsibility of tracking and reporting his target. This idea may be difficult for a small ship such as a destroyer, but is one which should be standard procedure whenever a ship has early warning duties. A search operator who has to divide his attention between searching for new targets and tracking previously detected contacts is faced with a difficult task. Long-range detection is improved if one operator is assigned the primary responsibility of detection. This does not relieve the tracking operator (or air controller, in the case of air search) from also searching for and reporting contacts not previously detected. The tracking operator's job is to supply ranges and bearings of contacts held on his scope to the summary plot or DRT.

Rarely is there enough space available in any ship to include all desirable features. As a result the CIC is designed so that it may best assist command in performing the functions of that particular ship. For example, one of the primary functions of CIC in a carrier is the control of aircraft. Accordingly, the carrier CIC contains more equipment for controlling aircraft than a ship type which normally would not be expected to do this. A general-purpose destroyer assigned the dual task of early warning and air controlling will have a problem of stationing both search and track operators due to the limited number of repeater PPI-scopes in its CIC. Both the air-search and air-track operators must work at the main console in this case. The track operator can sit at the console and track bogies already reported by the search operator. The latter can sit on a high, charthouse-type stool next to the console and have access to the A-scope, PPI-scope, and antenna controls. The search operator need give only an approximate range and bearing to new contacts and this would not interfere with the tracking operator.

This kind of temporary setup is sometimes necessary because CIC's are designed so that equipments are placed within the assigned space in such a way that a minimum of time and effort is required by CIC personnel to carry out their assigned tasks in a given condition of readiness, and in shifting to a higher or lower condition of readiness with ease and without interruptions. Usually only that equipment from which information must be obtained instantly, or which is necessary to effect control, is placed in CIC. Radar repeaters are always located in CIC, and in some cases the main console (radar set control or general control unit) may be located in CIC. Radar transmitters are not ordinarily placed in CIC.

The radar operator controls the radar to which he is assigned under the direction of the radar control officer (when assigned) or the CIC watch officer. The CIC watch officer often delegates this authority to the leading Radarman in CIC at the time (section leader or watch captain).

RADAR CONTROL OFFICER (RCO)

The radar control officer, either an officer or experienced petty officer, is responsible, under the CIC officer, for maintaining on the summary plot, tote board, and status boards an accurate and up-to-the-minute display of information concerning the air defense picture. The RCO must supervise all the variables in the radar operation to ensure maximum detection range and effective air control. These controls and settings include antenna rotation rate, pulse width, pulse repetition rate, receiver band width, range scales, and other settings which, left to the operator, might be adjusted for comfort rather than best radar performance. A prime example of sacrifice of efficiency to comfort is the use of the intensity control. A low setting on the intensity control makes the job of watching the PPI somewhat easier. Targets stand out more clearly against a dark background. With a low intensity setting, however, some targets cannot be seen at all. The intensity should first be adjusted so that the trace can barely be seen with the video gain turned all the way DOWN, then the video gain should be advanced to a medium setting with

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the DC restorer turned ON. This should provide best visual detection of a target on a PPI-scope.

The RCO mans a sound-powered phone circuit on a selector switch and can be in communication with the search operator, tracking operator, height finder, lookouts, and summary plot. In supervising the summary plotters, the RCO assists the evaluator by having unnecessary and outdated information scrubbed off and ensuring that information is plotted accurately and kept up to date.

HEIGHT-FINDER OPERATOR

The height-finding radar can be used for many purposes, such as long-range surface search, navigation, short-range search, etc. It is used principally for height finding. In order to combat an incoming raid effectively, altitude information must be obtained as soon as possible after initial detection. The primary responsibility of the height finder is the location of previously detected contacts with the object of determing altitude and sending this information to the summary plotters and air controllers. When the search operator reports a new target, the height-finder operator is coached by the search operator, and, if necessary, by the RCO onto the target. It is essential that the altitude-determining operators be advised of range, bearing, and composition of targets as soon as possible, because several altitude readings may be necessary. This is particularly true in equipment where altitude error varies with range. This error can be greatly reduced by coordination on the part of the air controller and height-finder operator in the use of relative altitude. When controlling aircraft, the altitude of the CAP is available and should be made known to the height-finder operator. Errors in altitude indications can be lessened by using the known interceptor altitude as a reference for getting bogey altitude. Assistance in altitude determination can also be obtained from the gunnery liaison officer when, under certain weather conditions, fire control radar detections exceed those of the height-finding radar. Fire control radar elevations must be converted to altitude for air controller use. Conversely, altitude information changed to elevation angles is an aid to the fire control radar acquisition.

The height-finding radar of the AN/SPS-8 series is also excellent search equipment and sometimes picks up targets well in advance of the other air-search or surface-search radars.

EMPLOYMENT OF RADAR

Since radar is CIC's primary source of information, we will first discuss the doctrine governing its use. It must be understood that a Radarman does not sit down in front of a radar and search the way he desires, or look for just anything. Radar doctrine is presented in the NWP 31 series and ATP-1(A), Vol. I. Additional information on the operation of radar is found in the NWP 33 series, NWP 34(A).

What is DOCTRINE? Doctrine, briefly, is a set of working principles—the rules which are followed by everyone in performing routine tasks. In the Navy, doctrine is laid down in a number of tactical and communication publications. We use them all. If we have a question in tactics, we refer to the appropriate tactical publication, ATP-1(A), Vol. I, for example. If we have a question in communications, we break out NWP 16, NWIP 16-1, and DNC 5(B). For questions which pertain specifically to CIC, we refer to NWP 31(A), and for additional information to the NWIP 31 series. In all CIC work we should perform every task in accordance with doctrine.

CIC DOCTRINE

On your ship you will have a CIC doctrine which has been written to explain the various functions that your ship's CIC must carry out, and the methods which have proved most effective for your ship in carrying out these functions. You must remember that this doctrine has been written by the personnel of the operations department of your ship specifically for your CIC. Although all CIC doctrines contain basically the same information, no two ships will carry out a function in exactly the same manner. Therefore, your ship's CIC doctrine shows you how your CIC is to perform its mission. A ship's CIC doctrine takes basic doctrine from the various NWP's and other doctrinal publications and amplifies it to suit the needs, capabilities, and limitations of your CIC.

RADAR GUARD ASSIGNMENTS

Radar guards are assigned to the ships in a formation by the officer in tactical command (OTC) or his representative. Assignments are made so that the formation can get the best possible radar surveillance protection. By assigning certain ships a responsibility, it allows radars not in use on other ships to be turned off for

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maintenance. Since guards are normally rotated among the ships, nearly all the ships will have maintenance time. When a radar guard is set, the use of the ship's radar is not limited to the special responsibility. On the contrary, surveillance over the entire scope must be maintained, consistent with the primary responsibility. Some of the radar guards are:

1. LONG-RANGE AIR SEARCH—This provides detection, recognition, and maintenance of continuous tracks of all aircraft, friendly and/or enemy, excluding aircraft within 30 miles when a short-range air-search radar guard is assigned. The dividing line between long-range and short-range guards is 34 miles from the formation. This is not a sharp line; the guards are to overlap about 5 miles each side of the dividing line.
2. SHORT-RANGE AIR SEARCH—Functions are the same as for long-range air search except that the guard extends about 39 miles from the formation.
3. MEDIUM-RANGE AIR SEARCH—This guard overlaps long-range air search and covers distances 30 to 75 miles from the formation.
4. LOW-FLYING AIRCRAFT SEARCH—Detection of low-flying close-in aircraft is the purpose of this guard.
5. LONG-RANGE SURFACE SEARCH—This guard performs early detection, recognition, and tracking of surface units, friendly and/or enemy, outside of the formation.
6. SHORT-RANGE SURFACE SEARCH—This guard furnishes close surveillance for early detection of submarines and small craft. The dividing line between long-range surface search and short-range surface search is approximately 5 miles beyond the screen. The dividing line is not sharp and the two guards overlap.
7. RECOGNITION GUARD—Electronic identification (IFF) is provided by the recognition guard.
8. ZENITH SEARCH—The zenith search guards the area directly overhead and above the search angle of equipment used for other types of searches.
9. STANDARD SECTORS are for use, as appropriate, for stationing tracking ships, detailing sectors of responsibility to radar guard ships, providing target designation sectors, and for other purposes. Standard sectors are prescribed in ATP-1(A), Vol. I.

There are other guards, such as intercept guards, but they will not be discussed in this text. The remainder of this chapter will discuss the techniques of operating surface-search and air-search equipments or general-purpose radar, given the name of "search radar," but actually used for many purposes.

SEARCH ADJUSTMENTS

If you are the radar operator at the main console—the search operator—then you must be prepared to set the transmitter pulse, receiver bandpass, and adjust the receiver gain and antenna scan quickly to a combination that will give the best results for any task assigned.

The manner in which you are told to search may come in various ways. You must learn your ship's policy regarding this. One of the common orders used by some ships is sent as follows: SPS-12 OPERATOR-THIS IS RCO--SET UP FOR GUARD ALFA. This order is followed by where to search and what to look for. Thus, you can set the controls in the proper position and begin to search accordingly. Another way of getting the word may be: RADAR OPERATOR—THIS IS CIC--WE ARE EXPECTING A TORPEDO ATTACK FROM LOW FLYING AIRPLANES--KEEP A SHARP LOOKOUT. You would then set up the radar for short-range air search. Radar guard assignments are found on status boards. You must always check the status boards before assuming the duties of search operator. For these resons, you must learn the radar guard assignments and the location and use of the various controls.

TRANSMITTER PULSE

Modern radars have two or more switch-controlled pulse lengths. The long pulse will increase the radar detection range, but will reduce the radar accuracy and range resolution. The short pulse position improves range accuracy and range resolution at a sacrifice in detection performance. Resolution means the ability of a radar to distinguish between two targets at the same bearing but slightly different range. (This topic is discussed in chapter 9.)

RECEIVER BANDPASS

The receiver bandpass control is usually combined with the transmitter pulse control, and

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adjusts the width of the radio channel to be passed by the receiver to conform to pulse length. The positions are:

1. NLP POSITION: This is the narrow bandpass, long pulse position. The narrow bandpass reduces the noise interference (radar grass) but distorts the echo. However, signal-to-noise ratio is improved to increase detection performance. Note that the receiver bandpass and transmitter pulse length work together as a team.
2. WSP POSITION: This is the wide bandpass, short pulse position. The wide bandpass allows a greater channel width to avoid distorting the echo but also passes more noise so that weak signals may be lost in the grass. The wide band and short pulse work together to produce better accuracy and resolution, but will cause a loss in detection range.

RECEIVER GAIN

The receiver gain control is very important because it sets the strength of both the signal and noise fed to the indicator by the receiver. The signal-to-noise ratio of the weakest target really determines the gain setting. The screen should always show a light background of noise to make sure that the weakest detectable signal will appear.

When starting any operation or exercise, receiver gain is adjusted after all the indicator settings have been made. Adjust the intensity so the trace is barely seen, but becomes bright as the gain is increased. When targets begin to appear, the final setting is made to show a light background of noise, against which ordinary targets stand out clearly.

During any operation or exercise, the gain is varied according to conditions. The proper use of the gain control is necessary in both the detection of a target and determining the target's composition.

When searching at long range, the echoes received are weak. To reduce the possibility of missing a pip at long range, the gain control must be kept somewhat higher than for short-range search.

Short-range search for small targets makes it necessary that the gain control be kept low. Targets such as submarine periscopes can be detected only at short range and are usually partly hidden by the sea return. If the gain control is not kept low, it is impossible to see the difference between sea return pips and pips from periscopes or partially submerged submarines. The gain is lowered whenever a strong target is to be closely examined. The effective use of the gain is a matter of practice.

ANTENNA SCAN

The antenna control group contains the manual antenna rotation crank, the automatic antenna rotation switches, and direction and speed of rotation controls. Proper use of these controls plays a large part in correct operation.

The radar "sees" a target very briefly each time its beam passes over the target area, and the returned echoes from a target are very small. The rate of scanning speed (rotation speed of antenna), compared to the size of the echoes received, will tell whether a target will be detected and produced on the indicator. For a small target, a slow scanning speed is desirable; for a large target, a faster scanning rate may be used.

For example, a radar has a 1-microsecond pulse width, a PRR of 1000 pulses per second, and a horizontal beam width of 2.5°. At an antenna scanning speed of 6 revolutions per minute (1 revolution in 10 seconds or 36 scanning degrees per second), we get 1 pulse every 0.036° (36 divided by 1000).

$$\frac{\text{Beam width}}{\text{Degrees per pulse}} = \frac{2.5}{.036} = 69 \text{ pulses}$$

Thus 69 pulses will be transmitted during the time the antenna is scanning the target area.

At an antenna scanning speed of 15 RPM, only 28 pulses will be available for the target area scanning time.

From the foregoing you can see that increasing the antenna rotation rate cuts down detection range posibilities and decreases maximum range.

SCOPE CONTROLS

The controls of the CRT usually require little attention after they have been set. When the CRT has been turned on, adjust the intensity or brilliancy control as described earlier. Be sure the sweep is no brighter than necessary, because the scope screen can be damaged easily by an electron beam that is too intense.

The focus control will sharpen the sweep. If the bright line appears fuzzy, adjust the focus

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control until the clearest and sharpest line is seen.

Should the sweep on the A-scope be out of position, adjust the horizontal and vertical centering controls until the sweep is in the correct position.

Occasionally the PPI sweep will not be at the center of the PPI screen. Radars are equipped with positioning controls to bring the sweep back to the center of the screen.

The astigmatism control is used to focus or sharpen a portion of the sweep on the A-scope. This is useful in determining the composition of a target. The portion of the sweep where the target appears can be sharply focused to produce the clearest image.

In most radars the range of a target is obtained by merely "cranking" the range step on the A-scope, and the range ring or tracking strobe on the PPI, so that it is aligned with the target pip. Range in yards or miles is read from the range counters. The brightness of the range markers on the PPI can be adjusted to the desired intensity.

The controls for operating the IFF equipment are usually mounted next to the radar repeater. They are discussed fully in Radarman 3 & 2, Vol. 2.

Use of delayed or off-centered presentation will aid in search. This has the effect of enlarging a small section of range without affecting cathode ray spot size. Thus, you are better able to separate two or more targets that are close together.

SPECIAL CIRCUITS

Many radars have antijamming controls mounted on the main console. These controls are designed to lessen the effect that enemy electronic interference has on the operation of our radars.

FTC is used against all types of jamming or jamming in general.

To obtain full benefit of these special circuits, it is necessary that you understand their use. Since all special circuits reduce signal return to some extent, they should be used only when necessary.

Sensitivity Time Control

The sensitivity time control (STC) reduces the sensitivity or gain of the radar receiver at the time the transmitter fires, and gradually increases the gain with respect to time so that full gain is reached before another firing of the transmitter. At that time the gain is again reduced and the process is repeated. STC is used to minimize the effect of sea return while providing sufficient gain for the detection of small targets at greater ranges. Note that STC affects only a portion of the entire range and can usually be varied in amount of control and in time duration.

Fast Time Constant

The purpose of the fast time constant (FTC) is to reduce individual signals to about 1.3 microseconds' duration—no matter how long they actually are--in order to break up large targets as seen on the scope, such as clouds or other weather effects. This permits seeing weak signals that otherwise would be hidden by such interference.

Amplifier Back Bias or Instantaneous Automatic Volume Control

The amplifier back bias (ABB) or instantaneous automatic volume control (IAVC) reduces the effects of overloading and saturation caused by long blocks of signals. Due to a usual 1-microsecond delay in operation, there is little effect on small targets, but large targets are affected considerably. ABB or IAVC is used with STC and/or FTC when you are trying to pick up small targets close to larger targets. It tends to separate the two targets instead of blocking them into one response.

Detector Back Bias

The detector back bias (DBB) operates with one-half microsecond delay to cut off all but one-half microsecond response of a sharply defined signal. DBB is used against well-defined masses (land, clouds, etc.) to allow identification of a particular target within this mass. In normal search, DBB cannot do anything that the proper use of STC, FTC, and ABB cannot do better.

High Video Pass

HVP is used specifically against electronic jamming. It cuts out the low-frequency responses, passing only the high video which produces a more narrow target width on the PPI-scope.

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Automatic Frequency Control

Automatic frequency control (AFC) is used to keep the frequency of the radar receiver in tune with the transmitter (magnetron). AFC avoids changing signal strength caused by drifting of the magnetron frequency. The AFC keeps the frequency of the local oscillator separated from the frequency of the received signal by the exact amount of the intermediate frequency.

Battle Short Switch

The battle short switch is used to override or short-circuit the safety interlock switches of the equipment, thus preventing a power failure due to gunfire shock or other causes. The battle short switch should be used only in an emergency or in order to check the equipment. The safety interlock switches will turn off the power to radar equipment if the equipment doors are opened, thus preventing accidental shock to personnel. During battle, the battle short switch is turned ON to override the safety interlock switches so that the equipment will operate continuously if gunfire or other shock jars the equipment doors open.

D-C Restorer

The D-C restorer is used to restore the time base of the indicator (deflection or intensity) to a static condition after passage of heavy or extended video signals, such as those produced by land masses, storm fronts, or some types of jamming. The D-C restorer normally should be left on for better discrimination between targets and for detection of small targets that are close to larger targets.

BASIC OPERATING PROBLEMS

As soon as you've operated a radar for awhile, you'll discover that certain operating problems arise again and again. These problems will be much the same, regardless of the type of radar. They deal with the use of the various basic controls and indicators. Check the following key questions. As an operator, how many of them have you asked yourself? How many can you answer?

1. RANGE SCALE: What scale should be used under what conditions? How often should scales be shifted?
2. GAIN CONTROL: This corresponds to the volume control on a radio. Should it be set at high, low, or medium?
3. ANTENNA ROTATION: Should the antenna be rotated continuously? How fast should it turn? Should it always search an area 360°? Should it be stopped to check a target, and for how long?
4. RANGE: How should ranges be obtained? Should the range step and associated dials be used when provided? Should estimated ranges be used?
5. BEARINGS: What are the different ways bearings can be read? Should the tracking strobe be used? Or should the mechanical cursor be used instead?
6. SCOPE: If the radar set is equipped with two or more types of cathode ray indicators, which should be used? Under what conditions is one preferable to another?

SEARCH PROCEDURES

Operating in various tactical situations will provide the answers to these questions for different types of radar sets. Also, your ship's CIC doctrine will supply the answers to many of them. However, each special circumstance will require variations which can be determined only by radar operating experience and common sense. Let us review some of the search procedures.

LONG-RANGE AIR-SEARCH OPERATOR

The long-range air-search operator receives instructions from the RCO. He will be stationed in front of the PPI-scope at the main console. He sets the controls for best reception and searches as follows:

1. PPI-scope should be maximum range or maximum detection range of the radar in use.
2. Pulse length in NLP.
3. Gain control adjusted for approximately 1/4-inch grass.
4. Focus control adjusted for thin trace at range of expected contact.
5. Receiver tune control adjusted for maximum reception.
6. AFC ON to counteract any voltage fluctuations or surges.
7. STC, FTC, and IAVC OFF.
8. Antenna adjusted for slowest rotation (not to exceed 5 RPM), with occasional manual sweep.

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After all controls are set, the operator should make an alternate inspection of the PPI-scope and A-scope. The RCO should have the operator relieved every 30 minutes, and should brief the relief operator on the tactical situation.

The operator should pay particular attention to the outer three-fourths of the scope. If a pip appears closer, don't hesitate to report it. Normally, the pips that appear at the outer edge (maximum range) will be very weak in intensity at first and may disappear at intervals. A good policy to follow upon contact is to mark the position with a grease pencil at first sight of pip, and take a range and bearing to the spot you marked. Report this range and bearing to the plotter immediately, then start the evaluation and tracking process.

MEDIUM-LONG-RANGE SEARCH AND TRACKER

The tracker is stationed at a remote PPI. He sets the range to the 80-mile scale, or off-center sweep, as necessary. PPI controls are set for best presentation. The tracker must be alert to relieve the long-range operator of tracking and reporting responsibilities, as directed by the RCO. The tracker should be relieved every 30 minutes, and his relief should be informed of the tactical situation.

HEIGHT-FINDER OPERATOR

The height-finder operator is stationed at a VL repeater in front of the main console of the height finder, next to a PPI repeater operator. Among the height-finder operator's duties are to—

1. Set the VL on 140-mile range with sweep expanded.
2. Ensure that AN/SPS-8 is tuned properly.
3. Use appropriate antenna rotation and scan rate. For example, long range air search use 1 RPM and scan rate of 300 scans per minute.
4. Use antenna elevation of 2° to 4°.
5. Train on target after being coached on target by search operator.
6. Work closely with PPI operator.
7. When actually measuring bogey altitude, use minimum possible range and NO sweep expansion to reduce size of pip.
8. Obtain altitudes periodically on all bogies and own CAP.
9. Compare bogey altitude with known altitudes.
10. Conduct search as directed by RCO.

SHORT-RANGE AIR SEARCH

The short-range air-search guard is used mostly when a torpedo plane attack is imminent, or low-flying planes are approaching from various bearings. When your ship has been directed to conduct short-range air search, the following procedure is recommended:

1. Set antenna rotation to fast.
2. Set the range scale at medium position.
3. Set gain control for maximum readability on the PPI.
4. Set pulse length on WSP.
5. Ranges and bearings are obtained in this manner: Since planes fly at great speeds, time spent obtaining ranges and bearings must be at a minimum. Therefore, ranges are estimated with reference to the range marks, and bearings are obtained with the cursor (mechanical or electronic, whichever is faster). It would be even better if you could train yourself to take bearings by using the outside bearing circle and estimate the bearings. However, for any degree of accuracy, always use the bearing devices provided.

LOW-PLANE SEARCH

The low-plane search is used when contact with low-flying planes may be expected. Ordinarily, in a task force with AEW planes, their objective will be low-flying airplane detection. The superior speed of aircraft enables airborne radars to search a larger area than is possible for shipborne radars alone in a given period of time. In addition, airborne radars operate at high altitudes and can search areas which are below the horizon of shipborne radars. They can thereby detect low-flying aircraft and surface targets which otherwise would escape detection until they were within range of the surface ships. This does not relieve a ship of the responsibility of detecting low flyers. Because of horizon limitations, however, first contact will not be made at more than 30 miles, so long-range characteristics are not necessarily important.

The low-angle search and height-finding radar such as the AN/SPS-8 should be used, when possible.

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SHORT-RANGE SURFACE SEARCH FOR LOW FLYERS

1. Operator at remote PPI-scope on 40-mile range scale.
2. Operator's controls set for best reception.
   a. Search 360°
   b. Fast, continuous antenna rotation.
   c. Narrow, long pulse setting.
   d. Receiver gain control set at normal (or slightly increased over normal).
   e. STC and FTC in the OFF position (unless OOD is required to use the bridge repeater for station keeping at close ranges, in which case operator must be able to use the STC switch).
3. Surface-search radars should be used for "back-up search" for snoopers.

It is particularly important to maintain a track of all friendly planes in the air when contact with the enemy is possible. Unless this is done, a snooper, or low-flying attack plane, may appear on the screen of the radar, unknown to the operator. At first you may believe it is impossible to keep track of the friendlies, but with the use of a grease pencil it is easy to mark the friendly contacts with a dot; then, if a contact appears out of the track, it will be readily apparent.

Here, again, speed in reporting is important. Thus, when contact is made, estimated ranges and bearings are sufficient. You may have to increase the speed of antenna rotation as the attackers close, and be prepared to shift range scales to the scale necessary to keep the target near the outer limit of the scope. You must be ready at all times to directly assist in the target designation and acquisition problem.

LONG-RANGE SURFACE SEARCH

The long-range surface-search control settings and procedures are essentially the same as for long-range air search. The gain control should be set for maximum readability of an echo at 30,000 to 60,000 yards. The exact setting must have been established previously for each set.

The antenna should be rotated at the slowest possible speed, with an occasional sweep using the manual control, if one is provided. You must be cautioned in using the antenna control, because someone else may be using the same radar for other purposes. The OOD, for example, may be using it for station keeping (especially at night or during low visibility), or for changing station in a formation. In such cases the antenna rotation control should be used with common sense.

The A-scope usually will show the initial contact before it appears on the PPI, because the A-scope is more sensitive. Look for weak pips that will appear at the outer edge of the scope. Mark the initial position with a grease pencil, then report the range and bearing of the spot to the plotter.

Attempt to classify the contact by using previous knowledge of the capabilities of your particular radar. Data concerning previously observed maximum ranges on different types of ships, and size of pip and its composition will be useful in making this decision.

SHORT-RANGE SURFACE SEARCH

Short-range surface search might be a search for submarines or PT boats, and should be conducted primarily when cruising independently. When cruising in company, the OTC normally will assign the search function of each radar in the force. The range scale used for short-range surface search will usually be the distance from the center of the formation to about 5 miles beyond the screen. If steaming independently, the range scale will be determined by the coverage required. The shorter the scale, the greater the probability of detection within range, although on some sets it may be found that the mid-range scale can be used to better advantage. The receiver gain should be varied during the entire search, its setting depending on the amount of sea return present and other tactical considerations. The operator should look for periscopes close aboard, increase the gain slightly, and search near the outer limits of the sea return area for surfaced submarines and small patrol craft. Remember that sea return is basically the same as an echo from a target and that it must be present if a small target echo is to be detected.

Operating experience will determine the correct gain setting for different amounts of sea return. Antenna rotation should be as slow as possible, and occasional manual searches should be made. New targets should appear on both the A-scope or the PPI at almost the same time, provided the gain is set high enough for PPI operation. These indicators should be

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observed alternately for equal periods of time to reduce eyestrain and monotony.

If contact is made, report it to the plotter, and this in turn will alert the CIC officer, gunnery liaison officer, and all others who need to know. If an attack is to be made on the target, you may be ordered to coach the fire control radar onto the contact. Once the fire control gear has picked up the target, there is no need for you to report to the gunnery personnel. Your efforts would next be directed to reporting the contact's range and bearings to the plotter. Be alert to coach the fire control gear back onto the target. This has to be done frequently, since the fire control directors have certain bearings, called blind areas, on which they cannot train. Do not become so interested in what is taking place that you neglect the search for new targets. If your ship makes contact with a submarine by sonar or radar, you will have an added responsibility—that of keeping track of the submarine and any ships designated to assist your ship in making the attack.

FLYCATCHER OR SMALL OBJECTS

Flycatcher, the detection of small objects, is used against sneak attacks by torpedo boats or suicide surface craft. It is used mostly while in port at anchor or making an invasion. The same procedure is used for objects with small reflecting areas such as periscopes, snorkels, buoys, or liferafts. The major problem is finding the object through sea return. Control settings are as follows:

1. PULSE LENGTH: This setting is not critical, although a short pulse may be helpful in distinguishing desired signal from sea return and providing better minimum range.
2. RECEIVER GAIN: Since sea return and periscope echoes are of about the same magnitude (strength), special gain circuits such as the STC must not be used. The gain control should be adjusted manually. An echo from a small object will appear in or near the edges of the sea return. The operator should reduce the gain setting to search close aboard, then gradually increase the gain to push the detection zone outward, repeating frequently.
3. ANTENNA SCAN: Antenna scan is the same as for long-range search—slow automatic scan with periodic manual scan.
4. SCOPE: The A-scope and PPI are about equally effective. However, in the presence of a formation of ships the PPI is more effective. The small object will usually produce a hard or glinting pip among the softer sea return signals.

ZENITH SEARCH

Zenith search is used to search the overhead region which the long-range radars do not cover.

Radar adjustments are the same as for low-plane search except that the zenith-search antenna is used, if available.

TARGET EVALUATION

CIC personnel must function with accuracy and speed, while exercising the soundest possible judgment. Although one individual—the evaluator during general quarters, the CIC watch officer during lower conditions of readiness or routine steaming—is specifically charged with evaluation, many CIC personnel, such as radar operators and plotters, will find it necessary to perform evaluation within the limits of their assigned tasks. For example, the radar operator evaluates the scope information and passes it to the plotter who displays it on various plots. From these plots the evaluator then makes his over-all evaluation of the situation. Thus, a radar operator gaining contact must be prepared to give an evaluation of the target. Special care must be exercised to avoid falling victim to enemy deception.

PERFORMANCE LOG

Make it a point occasionally to check through the radar performance log before going on watch, or at some convenient time. Data entered in the log concerning previously observed maximum ranges on different types of ships, and size of pip (in E-units, which we will talk about in a moment) and its composition when picked up, will be useful in making the decision of target's composition easier and more reliable. First check for IFF, then attempt to classify the contact by using previous knowledge of the capabilities of your particular radar. All ships keep a radar performance log or a radar contact log. These logs are kept at the main console of the radar, and when the operator picks up a target he enters the contact's designation, time of pickup, size of pip in E-units, and the time the contact fades from scope.

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E-UNITS

Referring to the actual height of the echo in inches is of little value because the height of the echo can be increased or decreased at will by merely varying the gain control. Even a weak signal can easily be "blown up" in this manner until it approaches saturation, but this increase may not help because of the corresponding increase in grass height.

Grass is a disturbance on the cathode ray tube screen, caused by noise in the tubes, static, etc. It shows up as a fuzzy, jumpy fur along the time base on A-scopes, and as many small, bright spots (sometimes called snow) on the PPI-scopes. It is always present to some degree, and pips smaller than the grass are very difficult to find. The grass seems to wave as real grass does, and may cover the pip. Grass height can be controlled by the receiver sensitivity (or gain) control; low sensitivity means a larger amount of grass. You know that the pip height can be made larger by increasing the gain, and smaller by reducing the gain. Since both the pip height and the grass height vary together, the pip size can be compared with the height of the grass. The comparison is made in E-units.

The E-unit system of discussing echo strength is standard in the Navy, and is a convenient system to use. By providing common terms with which to discuss the strength of echoes, confusion and misunderstanding are reduced. A small pip about the same height as the grass is an E-1 echo. It will always be difficult to detect, and only a wideawake operator will notice it. An echo of this strength might be overlooked on a PPI-scope by even the best operator. That is the main reason an operator should not devote all his attention to the PPI-scope.

The complete E-system includes five values: E-1, E-2, E-3, E-4, and E-5. As shown in figure 8-1, E-1 includes those signals whose ratio of signal to noise, or of pip height to grass height, is 1 to 1 (that is, the pip and grass are the same height). An E-2 echo is an echo whose pip is twice as high as the grass. An E-3 echo is one producing a pip four times as tall as the grass. If the pip is eight times as tall as the grass, we say we have an E-4 echo. An exceptionally great echo reaching saturation, or 16 times or more the height of the grass, is spoken of as an E-5 echo.

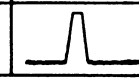
CODE DESIGNATION	SIGNAL TO NOISE RATIO	TYPICAL PATTERN	ECHO STRENGTH
E 1	1 TO 1 OR LESS		INTERMITTENT ECHO BARELY PERCEPTIBLE
E 2	2-1		WEAK ECHO
E 3	4-1		GOOD ECHO
E 4	8-1		STRONG ECHO
E 5	16 TO 1 OR MORE		VERY STRONG OR SATURATING ECHO

Figure 8-1.—Echo units

An E-1 echo is very weak, an E-2 echo is weak, an E-3 echo is good, an E-4 echo is strong, and an E-5 echo is very strong. The E-5 echoes are the ones we get from large nearby targets.

IFF

IFF is a special system used in conjunction with air-search radar, which provides rapid information as to whether a target is friendly or enemy. This instantaneous identification will prevent you from wasting time on the evaluation of friendly craft. It must be remembered, however, that an IFF reply will not always indicate on every friendly. There may be times when the IFF of a friendly craft is inoperative, and in such cases the contact must be treated as "enemy" until positively identified. There is also the possibility that the IFF system aboard your ship may be temporarily out of commission. Alertness will pay dividends. For more details on IFF see Radarman 3 & 2, Vol. 2.

The nature of the contact and the number and size of objects it comprises may be determined by examining the echo it produces upon the radarscope. You must learn to do this quickly and accurately so as to interrupt the search as little as possible. The following information may aid you in the job of evaluation, but experience is the best teacher.

Long Range

The best method of detecting extremely long range is to use the A-scope. If the situation

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permits and the CIC watch officer concurs, stop the antenna and use the expanded portion of the A-scope. Also look for echo beat, echo spikes, and target movement.

1. ECHO BEAT: The beat or rhythm of a signal is usually the best means of target evaluation. An A-scope is necessary since the persistence of a PPI will not allow it to follow the beat. A plane will have a fast beat; a ship will have a slow beat; and land will show a stationary beat.
2. ECHO SPIKES: Targets that are too close to be separated by radar resolution may produce echo spikes on the one large pip. These spikes are revealed upon examination with an A-scope.
3. TARGET MOVEMENT: A target that moves with the course and speed of the wind is cause for suspicion. For example, it may prove to be some form of enemy deception. Movement is best seen on the PPI-scope. Make it a practice to mark each pip on the scope with a grease pencil and then note the time alongside without obscuring other targets. If you do this, it will be readily apparent if the target is a plane, land mass, or surface craft. The pip from the plane will change position on the scope rather rapidly, whereas one from the ship will be slow. Land will move the reciprocal of own ship's movement.

Short Range

Evaluation of rapidly closing targets first detected at short range must be made by comparison with known movements from other sources. This is another reason why the summary plot must be accurate and up to date.

RADAR TRACKING PROCEDURE

In addition to searching for targets, Radarmen are called upon to perform the function of tracking as well. When greater tracking accuracy is desired than is obtainable with a search radar, a fire control radar can be used. It is designed primarily for tracking accuracy.

Our discussion will be confined to search radars normally used for tracking targets after they have been detected. Now that you know the significant controls and how they influence search performance, let us discuss those controls and their effect on tracking accuracy and resolution.

SIGNIFICANT CONTROLS

As already pointed out, the principal controls that have the greatest influence on radar performance are made variable so that the operator may select the best combination for the task at hand.

Transmitter Pulse

A long transmitter pulse (NLP) is provided for search purposes, but to obtain the accuracy and resolution needed for tracking, a short pulse (WSP) is employed. Note that the increased resolution and accuracy are accomplished by sacrificing some detection range.

Receiver Gain

Improved contrast for tracking may be obtained by reducing the receiver gain. Furthermore, since the value of transmitter pulse length and antenna beam width are actually average values, reducing the receiver gain narrows the pulse length and beam width for better accuracy and resolution.

The antenna scan may be varied according to the requirements and the operator also has a choice of range scales.

TRACKING PROCEDURES

A variety of procedures is available for use, according to the degree of accuracy and resolution needed, and the willingness to sacrifice search performance to obtain them.

Normal Tracking

A "track-while-scan" procedure is used while the radar is set up for a normal search condition. Bearings and ranges are obtained without interfering with the search, preferably from a second indicator by another operator. While this procedure is not the best for accuracy and resolution, it usually is satisfactory for most purposes.

Multiple Target Tracking

A "track-while-scan" procedure is used to handle more than one target, usually at short or

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medium ranges. A faster antenna scan is used, together with a shorter pulse and lower receiver gain, for improved accuracy and resolution.

Accurate Tracking

When tracking accuracy is required, as in fire control, missile guidance, or navigation fixes, search procedure is often abandoned for maximum accuracy in tracking. The shortest available pulse and low receiver gain are used, and the antenna is stopped on the target so that bearing and range can be measured carefully and accurately.

Shifting Procedure

Changing radar procedure should be directed by the radar control officer (or watch supervisor, when delegated). You should be prepared to shift procedure as the occasion demands. For example, you may conduct long-range search until a contact is made, then shift to accurate tracking for one or two plots, then resume long-range search.

TRACKING OVER LAND

Tracking airplanes over land is not as difficult as it may seem, although it is an art that requires a lot of practice.

When planes fly over a land mass, the echoes merge with land echoes and cannot be seen on the PPI-scope. Use the A-scope and the shortest range scale on which the plane can be seen, if you intend to track it. With the antenna in manual rotation and the gain control set so that land echoes are not saturated, train slowly through the land mass, watching for a bouncing pip among the steady ones. This indicates the presence of a plane. Adjust the antenna until the pip shows the maximum activity. You may then read the range and bearing of the plane almost as accurately as if the land were not there. Practice this technique on friendly airplanes whenever you get the chance.

SPECIAL TRACKING PROCEDURES

Several special tracking procedures to meet a specific need, usually temporary, may be employed. Some of these special procedures are: CIC assistance in navigation and piloting, station keeping, maneuvering the ship into station, aircraft control, auxiliary fire control, and boat wave tracking.

CIC ASSISTANCE IN NAVIGATION AND PILOTING

The basic equipment and organization of CIC normally enable it to give general assistance to command in connection with navigation, and specific assistance in piloting.

Although radar can be of great value in piloting, it is subject to certain limitations which must be understood by you as a radar operator or plotter in a navigation problem.

Navigation by radar may be a combination of several procedures: long-range search for making landfall; normal tracking of land masses for offshore piloting; multiple target tracking of buoys and shipping in a channel; and accurate tracking of prominent landmarks for accurate fixes.

For navigational purposes, short-range targets can be observed more clearly if the receiver gain control is set properly. The proper setting will eliminate filling-in of the PPI from sea return and false signals from minor lobes. (Minor lobes and false signals are discussed in a later chapter.) The STC control will aid in reducing sea return so that a higher gain setting may be used. A short pulse length and broad bandwidth should be used to obtain the best definition. However, the operator should switch to a long pulse width and narrow bandwidth when maximum range is required. If prior to entering or leaving port, the radar set is tuned, there should be no difficulty in receiving echoes from small objects such as small craft, bell buoys, or navigational hazards.

Radar Piloting

Piloting is a form of navigation near land using landmarks, aids to navigation, and soundings. Therefore, one of the most useful functions of the surface-search radar is its contribution to piloting. You should, however, understand the limitations involved when radar is put to such use. Unless you know the contour and composition of the land that is reflecting the radar energy you are never safe in reporting the range to the nearest land. If you are ranging on a sharp cliff that rises directly upward from the water's edge, you are safe in assuming that the correct range to the nearest land is the range obtained from the radar screen. If, on the other hand, the land rises gradually from the water's edge to a mountain range some distance inland, there's a good chance that your radar is ranging on an echo produced by the mountain range and not on the

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low-lying beach that is nearest your ship.

It is almost impossible to determine the exact point of reflection from a sloping surface, so that even an error of a few hundred yards might prove disastrous in close piloting work. Always keep a contour map of nearby land available for reference when navigational information is required.

After careful comparison of radar maps with contour maps of familiar land, you may become expert in estimating reflecting surfaces from unfamiliar shorelines.

The beam width of the antenna must also be considered in an attempt to make a radar picture of a shoreline. The examples in figure 8-2 show how the shoreline changes as the ship moves from one position to another. Notice that the harbor has been completely obscured, in all instances, by the radar shoreline, and that a ship, which might be situated anywhere inside the shaded areas, would not appear on the scope, due to beam width distortion. The explanatory remarks in the last drawing are applicable in all the others.

All the examples assume that equal reflection is obtained from all points along the shoreline. You'll find this is rarely the case. It is a necessary assumption for the purposes of discussion. The radar shoreline will differ from the actual shoreline by an amount depending on the beam width of the antenna, the contour and composition of the land in the immediate vicinity of the shoreline, the bearing of the ship from land at any given time, and the amount of receiver gain used.

It is impossible to describe all the situations that might exist in ranging upon a shoreline with radar. Each problem has its own characteristics and you'll have to treat each individually.

More accurate fixes can be obtained if the smallest available land mass is used. On the PPI shown in figure 8-3, points X and Y would give the best navigational fix.

It is often helpful to plot the range and bearing backward from your estimated position and analyze the chart to see if there is a possible reflecting surface. Good and bad ranges may be identified in this manner. Remember that the chart itself may be in error, so you must consider its known accuracy when using this procedure.

Station Keeping

When cruising in company with other ships, your ship will be assigned a definite position in the formation. Staying in this assigned position is the responsibility of the officer of the deck and is called station keeping. The OOD has a remote repeater on the bridge that he uses to obtain ranges and bearings on the reference ship to enable him to determine if the ship is on station. Usually a plot of the ships in company is kept directly on a radar repeater in CIC. If the OOD becomes engaged in something else momentarily, CIC must be prepared to furnish ranges and bearings on the guide to him. This information is relayed to him via a phone talker stationed on the bridge.

Station keeping may require normal tracking or accurate tracking, depending upon the accuracy needed. Note that the STC control may provide the reduced gain needed at short ranges without interfering with the gain needed for search at long range.

The normal requirements of station keeping are such that you must rotate the antenna continuously, using the short-range scale on the indicator. Bearings and ranges on the guide, or on any other ships in the formation, may be obtained directly from the PPI-scope, by using the electronic cursor to bisect the pip, then cranking the range strobe out until it bisects the target. The bearing and range counters may then be read. To be able to identify the pips on the screen, it has been found useful, when proper conditions prevail, to maintain a plot on the face of a remote PPI with a grease pencil. Another method is to mark the scope with a grease pencil where the guide ship should appear when you are on station. Any indication of incorrect position will then become immediately apparent. Should this happen, it should be brought to the immediate attention of the CIC watch officer.

Search should not be forgotten when station keeping. Adopt a plan of shifting range scales and varying receiver gain. Turn the gain down only when obtaining the necessary station keeping information.

Remember, also, that the OOD may be using the radar on a remote repeater on the bridge, and any adjustment on the radar set control or general control unit will affect his presentation. Most OOD's and radar operators like to work with the receiver gain control far enough advanced to produce strong signals with the snow effect barely visible on the indicator. This ensures a clean screen. The gain should not

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be advanced beyond the point where the signals on the indicator begin to be lost in the snow if the radar is to be used for station keeping.

Maneuvering Situation

A change of formation or reorientation calls for a special radar operating method to guard against possible collision. Essentially it is a multiple target tracking procedure with fast

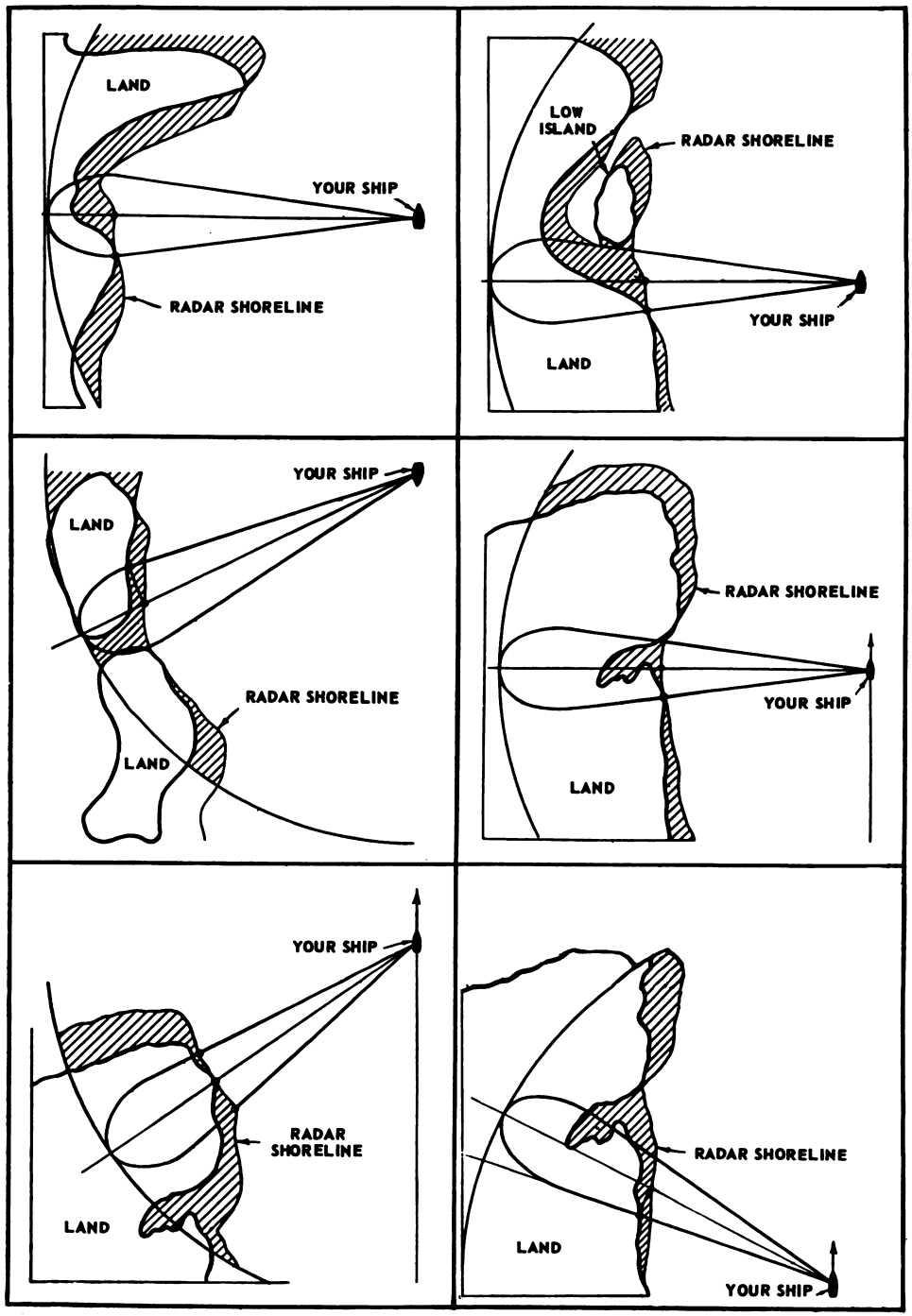

Figure 8-2.—The effect of ship's position on apparent radar shoreline.

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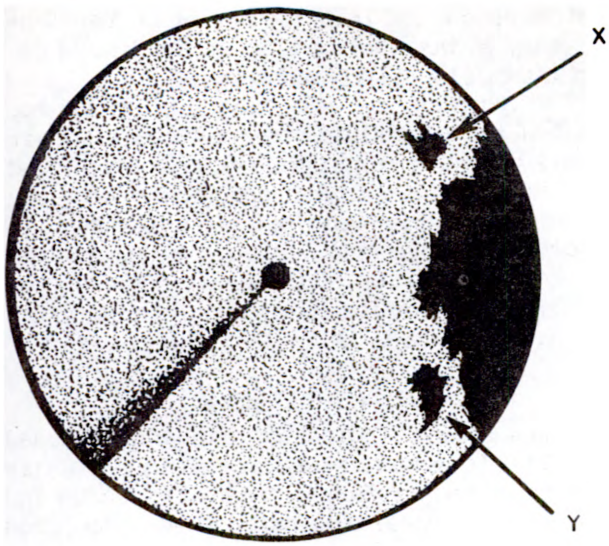

Figure 8-3.—Small land masses provide accurate navigational fix.

scan and high resolution. This requires a scope with a range scale just large enough to include the formation. A rapid series of plots on the guide and ships near to you should be made and reported to conn, preferably with the lookouts on the same circuit to combine visual and radar information. A formation plot, with ships identified, should be drawn on the scope or arranged on a plastic overlay, so that a ship failing to conform to the maneuvers can be spotted immediately.

Aircraft Control

Aircraft control will not normally be performed by you, but you must be familiar with the radar adjustments for good controlling.

Aircraft control is defined as the direction of and/or the assistance to the pilot of an aircraft by personnel not actually engaged in the flight. By using sources of information not available to the pilot, air controllers are prepared to exercise whatever degree of control may be required for the successful accomplishment of a mission.

Control of combat air patrol (CAP) for interceptions is usually conducted from a normal or multiple target tracking procedure. When a greater data collection rate is needed, as in handling a high-speed jinking (zigzagging) raid, a special procedure may be needed. By sector scanning the area containing both CAP and unidentified aircraft (bogey), the interception data may be improved. This procedure is especially valuable when working with off-center or delayed scope presentations and with radars that scan in elevation as well as in azimuth.

Auxiliary Fire Control

If your ship has no fire control gear, the gunnery officer may have to depend greatly on the surface-search radar for target information.

As a radar operator, you must furnish more accurate ranges and bearings than those obtained by getting them on the fly. You must stop the antenna on the target in order to get accurate ranges from the A-scope and bearings from the bearing indicator. If no A-scope is available, select the method of obtaining range and bearing data according to the instructions for the type of radar you're operating.

For radar spotting, the antenna must be fixed on the target to observe the projectiles in flight so that you may note the splashes on the radar indicator.

The torpedo control work may be delegated to the surface-search radars in CIC if the fire control radar is assigned a target other than the one to be attacked by torpedoes.

Tracking Through Interference

An enemy may introduce several forms of interference or take advantage of natural interference in order to deny us the opportunity to plot an adequate track. Yet, if we are to carry out our mission, tracking the enemy may be necessary.

Window is a type of echo interference deliberately introduced to screen the target. Window is made of strips of metal foil cut to one-half the wavelength of the radar frequency to be jammed or deceived. It is normally dropped from aircraft, but can be fired from certain types of guns. When radar energy strikes these strips of foil, they reradiate the energy back to the radar and produce pips on the scope. A short pulse is needed for improvement of echo resolution. The receiver gain should be tried at several settings. Sometimes at low gain the target will show above the interference. Sometimes high gain will show the target within the interference. The FTC (fast time constant) of IAVC (instantaneous volume control) will help. Look at the edges of the interference. If the echoes are caused by a plane dropping window, you can detect the plane at the leading edge of the interference. More about window is contained in Radarman 3 & 2, Vol. 2.

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Noise is another type of interference that may be introduced into the radar by an enemy jammer. By using the NLP position, the signal-to-noise ratio may be improved. The procedure for tracking through noise interference is the same as for echo interference, except the IAVC may be more of a hindrance than a help. Note that it is always possible to take bearings on the jamming source.

CONTROL OF SMALL CRAFT

For the effective control of small craft, CIC personnel must have a knowledge of both the radar reflecting characteristics of small craft under their control and of the tactical capabilities and limitations of such craft. As a Radarman Third or Second, you will not be controlling small boats but you will be doing the plotting and operating the radar.

Examples of the type of control which may be exercised include (1) directing landing craft to specified beaches, (2) stationing of control or picket boats in amphibious operations, (3) aiding small minelaying or minesweeping boats, and plotting positions of swept areas and minefields, (4) directing PT boats on coastal patrol, (5) directing crash boats, and (6) controlling smoke boats or even exercising control over liberty boats.

In controlling assault craft during a ship-to-shore operation, CIC must be thoroughly familiar with the operation orders, particularly with the communication plan and the boat employment plan. Appropriate charts showing boat lanes, reference points, approach schedules, and landing diagrams must be available. Predetermined time, speed, and course schedules should be displayed on special status boards. Communications must be established between the controlling officer in CIC, the debarkation officer, and the boat wave commanders. Control passes from the debarkation officer to the controller as each boat wave is dispatched for the line of departure. A method of passing boat wave control from the parent or dispatching ship to the control ship at the line of departure will be clearly established.

The problem of boat tracking is not too great if the capabilities of your radar set are understood. The minimum range of your set must be considered. As soon as the boat you desire to track is identified, the task then is to report the range and bearings to the plotter while keeping track of the boat on the scope. The radar set is usually adjusted the same for boat tracking as it is for small object search.

GUNNERY LIAISON

When groups of attacking planes have closed to within 20 miles of the force, it is necessary that close cooperation between the search and fire control radars be maintained. The guns must often be coached on, directly from the air-search radar, or placed on the target by an electrical target designation system connected to that radar. It must be understood that radar is an aid to the fire control problem. Missiles, guns, and other weapons are of no value unless targets (air or surface) are detected. The radar operator should be the first to detect these targets. There are other means of detecting a target, such as the lookout, but by the time a lookout spots a target it may be too late. This explains why ALL information that you obtain from the scope must be reported to the plotter to be displayed so that all personnel in CIC who need the information can get it without delay. SPEED IS OF THE ESSENCE. Make it a rule to report everything that appears on the scope. You will be told to continue reporting or to "scrub" (cease reporting, but keep under observation). Even if you are not reporting a target that appears on the scope, be sure to mark it with a grease pencil so you will be able to tell without a doubt if a new contact pops up. Even the most experienced operator cannot keep the scope picture clear in his mind without marking the pips.

QUIZ

1. How can we become expert in developing a well-organized defense team in CIC?
2. What should you, as the search operator, do prior to any operation or exercise?
3. Why is a tracking operator necessary?
4. The radar operator controls the radar to which he is assigned under the direction of whom?
5. Where may you find the answers to questions relating to CIC?
6. What effect does the transmitter pulse have on radar search?
7. Why must the brilliancy control be kept as low as possible?
8. If the sweep on the A-scope is out of position, what controls do you use?

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9. What must be taken into consideration while using special circuits?
10. Outline the procedure for long-range air search.
11. (a) Who is responsible for evaluation during GQ?
    (b) On what does he base his evaluation?
12. What is the purpose of the E-unit system?
13. If you receive no reply from an IFF challenge, does it indicate the target is enemy?
14. How can an airplane flying over land masses be distinguished from the land?
15. (a) What precautions must you observe when your search radar is acting as an auxiliary to fire control?
    (b) What is done to prevent this danger?
16. What rule should you follow concerning reporting pips that appear on your scope?

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CHAPTER 9

FACTORS AFFECTING RADAR

MAINTENANCE FACTOR

There are many factors, or elements, that affect efficient radar performance, not all of which are completely understood. One of the principal factors is maintenence. The ability of maintenance personnel (Radarmen and Electronics Technicians) to keep the equipment operating at peak efficiency will influence the over-all capabilities and limitations of the radar. Many of these limitations are a result of radar design. If you recognize these limitations, and their causes, you will be better able to determine the type of performance to expect from your radar.

KNOW YOUR EQUIPMENT

Another important factor is the radar operator's knowledge of his equipment. He must know the maximum and minimum ranges at which he can expect to pick up various targets, range and bearing accuracy of the gear, and range and bearing resolution. If he is operating a height finder, he also must know the altitude determination and accuracy and the altitude resolution. Information on these factors is contained in the instruction book for each radar.

FACTORS AFFECTING MAXIMUM RANGE

FREQUENCY

The higher the frequency of a radio wave, the greater is the attenuation (decrease in power) due to weather effects. Lower radar frequencies have, therefore, been generally superior for extremely long ranges. However, recent developments in power generation have made possible high-powered, high frequency pulses able to overcome the undesirable effects of attenuation previously associated with high frequency waves. This, in turn, has permitted the use of higher frequencies for relatively long ranges which has the advantage of allowing the use of smaller antennas.

PEAK POWER

The peak power of a radar is its useful power. Range capabilities of the radar will increase with peak power. Doubling the peak power will increase the range capabilities by about 25 percent.

PULSE WIDTH

The longer the pulse width, the greater the range capabilities of the radar. This is due to the greater amount of pulse energy sent out, plus the fact that narrow band-pass receivers may be used, thus reducing noise level.

PULSE REPETITION RATE

The PRR determines the maximum measurable range (MMR) of the radar. Ample time must be allowed between pulses for an echo to return from any target located within the maximum workable range of the system. Otherwise, returning echoes from the more distant targets will be blocked by succeeding transmitted pulses. This necessary time interval fixes the highest PRR that can be used. The lower the PRR, the greater the range. However, the PRR must be high enough, so that sufficiant pulses will hit the target, and enough will be returned. The maximum measurable range can be determined by dividing 82,000 by the PRR.

BEAM WIDTH

The more concentrated the beam, the greater the range capabilities for a given amount of transmitted power.

RECEIVER SENSITIVITY

The more sensitive the receiver, the greater the detection range of the radar. Sensitive receivers are easier to jam, however, and interference will show on the scope more easily.

INDICATORS

The choice of the type of scope to show weak pips will add to the capabilities of the radar. The

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deflection modulated A-scope is more sensitive to weak echoes than the intensity modulated PPI-scope. In some cases, when using the AN/SPS-8 radar, a target can be seen on the RHI (range-height indicator) before it shows on the PPI.

CONDUCTING MATERIALS

Targets that are large can be seen on the scope at greater ranges, provided line-of-sight exists between the radar antenna and the target. Conducting materials such as metals give the best reflections, but nonconducting materials (wood, for example) will also return echoes, even though much weaker ones.

ANTENNA ROTATION RATE

The more slowly the antenna rotates, the greater the detection range of the radar. Thus, an antenna which is not ratating would afford the greatest range in the direction it is pointing, within limits of the radar. For tactical reasons, we do not stop the antenna from rotating and point the antenna beam at a target, except momentarily, and then only to gain information on composition of a target.

FACTORS AFFECTING MINIMUM RANGE

The minimum range capability of a radar is primarily determined by the pulse width. It is equal to one-half the pulse width of the radar (164 yards per microsecond of pulse width).

RECOVERY TIME

The recovery time of the duplexer and the receiver may extend the minimum range at which a target may be detected beyond the range set by the pulse width.

SEA RETURN

Sea return may clutter the indicator beyond the minimum range established by the pulse width and recovery time.

SIDE LOBE ECHOES

Targets detected by the side lobes of the antenna beam pattern are called side lobe echoes. When operating near land or large targets, side lobe echoes may clutter the indicator and prevent detection of close-in targets, without regard to the direction in which the antenna is trained.

VERTICAL BEAM WIDTH

The minimum range at which high-flying aircraft may be detected depends on the vertical beam width of the radar. Small surface targets may also escape the lower edge of the vertical beam when close in.

FACTORS AFFECTING RANGE ACCURACY

CALIBRATION

The range accuracy of the radar depends upon the exactness with which the time interval between the transmitted pulse and the echo pulse can be measured. Calibration is the correction of the measuring device so that it will conform to a fixed standard of measurement. Ordinarily the Electronics Technician will do the actual calibrating of the radar, but he will not know that it needs to be done unless you tell him.

Checking Calibration

The calibration of your radar should be checked at least once each watch, and more often if you have reason to doubt the accuracy of the calibration. A radar calibrated within a few minutes after it is turned on should be checked 30 minutes later, or after the set has had sufficient time to thoroughly warm up.

Checking the calibration is a rather simple operation and takes very little time. Turn on the range marks or rings. Select the 1-mile marker scale. Set the scope scale to below 34 miles. Adjust the range strobe to check calibration of the first ring. The range counter should match the reading of the first ring (2000 yards). Repeat this process for the first five mile markers. If the range ring and range counter differ approximately 50 yards, then the equipment is out of calibration and the error should be reported to the ET's. Use range rings at 1-,5-, and 20-mile settings. Repeat the calibration check, using a range scale setting above 34 miles. Observe the origin of center of scope when shifting to the larger scale. If it jumps more than three-sixteenths of an inch, the calibration is in error.

There are other methods of checking the calibration, to be performed by the ET's. They will check out all the indicators before the ship gets underway. During the day the check described above can be made. The type of scope you operate may not work exactly as the typical radar described, but it will follow closely. In any case, if the range strobe and range counters

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match, you can assume the indicator is calibrated.

ALIGNMENT OF MARKER

One factor affecting the accuracy of range measurement is the ability of the operators to align the range marker with the echo pip. On long range scales, it is difficult to align the pip and range marker exactly, because small changes in the range crank do not cause noticeable range strobe changes on the scope. Thus, the range accuracy of radar differs with each range scale used. In general, the longer the range scale, the less accurate the ranges.

FREQUENCY DRIFT

Errors in ranging can also be caused by slight variations in the frequency of the oscillator used to divide the sweep into equal range intervals. If such a frequency error exists, the ranges read from the radar will generally be in error by some small percentage of the range. The range accuracy of a radar is often given, for example, as plus or minus 15 yards, plus or minus 0.1 percent of the range. The first term represents the fixed errors in the system plus the error of aligning the echo and reading the dial. The second term expresses the error that may be introduced because of the tolerance permitted in the oscillator frequency. Using the figures above, the maximum error in the range reading for a target at 30,000 yards would be plus or minus 45 yards.

Baking In

To reduce range errors caused by frequency drift, precision oscillators in radars are usually placed in a constant-temperature oven. The oven is always heated, so there is no drift of range accuracy while the rest of the set is warming up.

FIXED ERROR

The zero reference for all range measurement must be the leading edge of the transmitted pulse as it shows on the indicator. Since part of the transmitted pulse leaks directly into the receiver without going to the antenna, the time required for R-F energy to go up to the antenna and return from the antenna to the receiver as an echo results in a fixed error. This error causes the indicated ranges to be greater than their true values. To correct for this error and for other delays in the system, a negative zero set must be applied to the indicator. This correction adjustment is made by the ET's.

Trigger Delay Circuit

A device called a trigger delay circuit is used to eliminate a fixed error. By this means the trigger pulse to the indicator can be delayed a small amount, in steps of 0.05 or 0.1 microsecond. Such a delay results in the sweep starting the instant an echo would return to the indicator from a flat plate right at the antenna, not at the instant that the pulse is generated in the transmitter. Once the trigger delay is properly set, it should need no further attention, other than periodic checking to ensure that the sweep actually starts at the true zero instant of the radar.

LINE VOLTAGE

The accuracy of range measurement depends on the constancy of the line voltage supplied to the radar equipment. If the supply voltage varies more than approximately 10 percent from its nominal value, the ranges indicated on the radar may be unreliable. Usually this will happen only momentarily, and after a short wait the ranges will be accurate.

RANGE RING

On some PPI-scopes, range can be estimated only by reference to range circles produced either electronically or scribed in a plastic overlay on the screen. At best, range can be estimated within 1 percent of the sweep length by this means, but a more reasonable accuracy to expect would be 2 or 3 percent. Thus, the error in the estimation, in yards, depends on the range scale. If the PPI is set to the 40-mile scale, the range of a target would be within 150 to 250 yards of the value determined by the operator. If an 80-mile scale is used, however, the ranges determined are within only 3000 to 5000 yards of the true range.

Reducing Range Error

A range ring has been provided on some PPI-scopes as a means of reducing range error. The

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diameter of this ring can be varied by the operator the same as the position of the range step on the A-scope.

RANGE STROBE

Some radar repeaters have a range strobe similar to the range ring. Instead of a complete circle, however, the range strobe is a small, bright spot. The range strobe crank (range crank) controls the setting of the range strobe and measures distances from the origin of the sweep or electronic cursor. Ranges are read from the range counters in the usual way. Range accuracy of your radar depends on how well you align the strobe with the pip. Radar repeaters are calibrated so that the strobe should be placed on the leading edge of pips for most accurate ranging. The brightness of the strobe contributes to the range accuracy to some degree. For best results the strobe should be just bright enough to see and should be focused as sharply as possible.

FACTORS AFFECTING RANGE RESOLUTION

Individual ships in a group will not show up separately on your scope unless there is considerable distance between the ships. The ability of a radar to give separate indications of individual targets is called resolution. Figure 9-1 will give you a better understanding of bearing and range resolution.

Bearing resolution is defined as the ability of a radar to resolve between two targets at the same range but with different bearings. These targets must be separated by a certain minimum of degrees before individual targets can be seen.

Likewise, range resolution is the ability of the radar to resolve between two targets on the same bearing but with different ranges. These targets must be separated by a certain distance before they appear as individual pips on the scope.

The principal factors that affect the range resolution of a radar are the width of the transmitted pulse, the receiver gain, and the range scale. A high degree of range resolution requires a short pulse, low receiver gain, and a short range scale.

PULSE WIDTH

Two targets on the same bearing, close together, cannot be seen as two distinct pips on the scope unless they are separated by a distance greater than one-half the pulse width (164 yards per microsecond of PW). If your radar set has a pulse width of 5-microseconds' duration, the targets would have to be separated by more than 820 yards before they would appear as two pips on the scope. Let us see why this happens.

Radio-frequency energy travels through space at the rate of approximately 328 yards per microsecond. Thus, the end of a 1-microsecond pulse traveling through the air is 328 yards behind the leading edge, or start, of the pulse. If a 1-microsecond pulse is sent toward two objects on the same bearing, separated by 164 yards, the leading edge of the echo from the distant target will coincide in space with the trailing edge of the echo from the near target. As a result, the echoes from the two objects blend into a single pip, and range can be measured only to the nearest object. The reason for this blending is illustrated in figure 9-2.

In part A of figure 9-2, the transmitted pulse is just striking the near target. View B shows energy being reflected from the near target, while the front of the transmitted pulse continues toward the far target. In part C, 1 microsecond later, the transmitted pulse is nearly striking the far target, and reflected energy from the near target has traveled 164 yards back toward the radar. The reflection process at the near target is only half completed. Echoes in D are

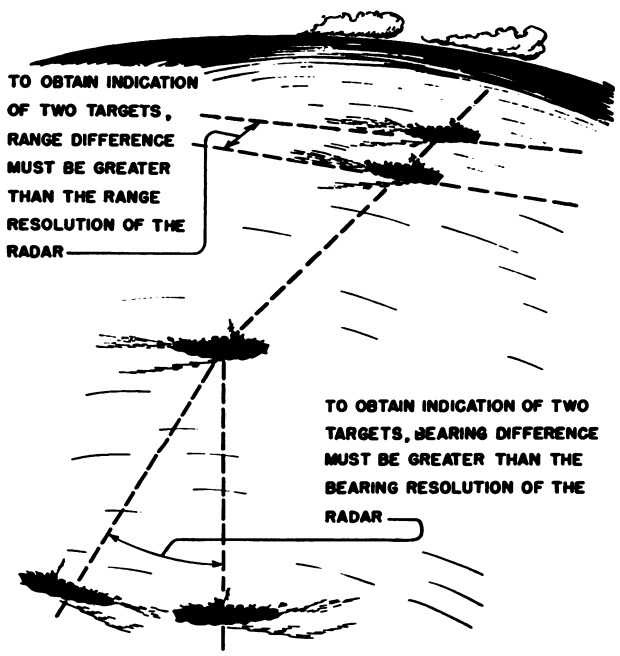
TO OBTAIN INDICATION OF TWO TARGETS, RANGE DIFFERENCE MUST BE GREATER THAN THE RANGE RESOLUTION OF THE RADAR
TO OBTAIN INDICATION OF TWO TARGETS, BEARING DIFFERENCE MUST BE GREATER THAN THE BEARING RESOLUTION OF THE RADAR

Figure 9-1.—Bearing and range resolution.

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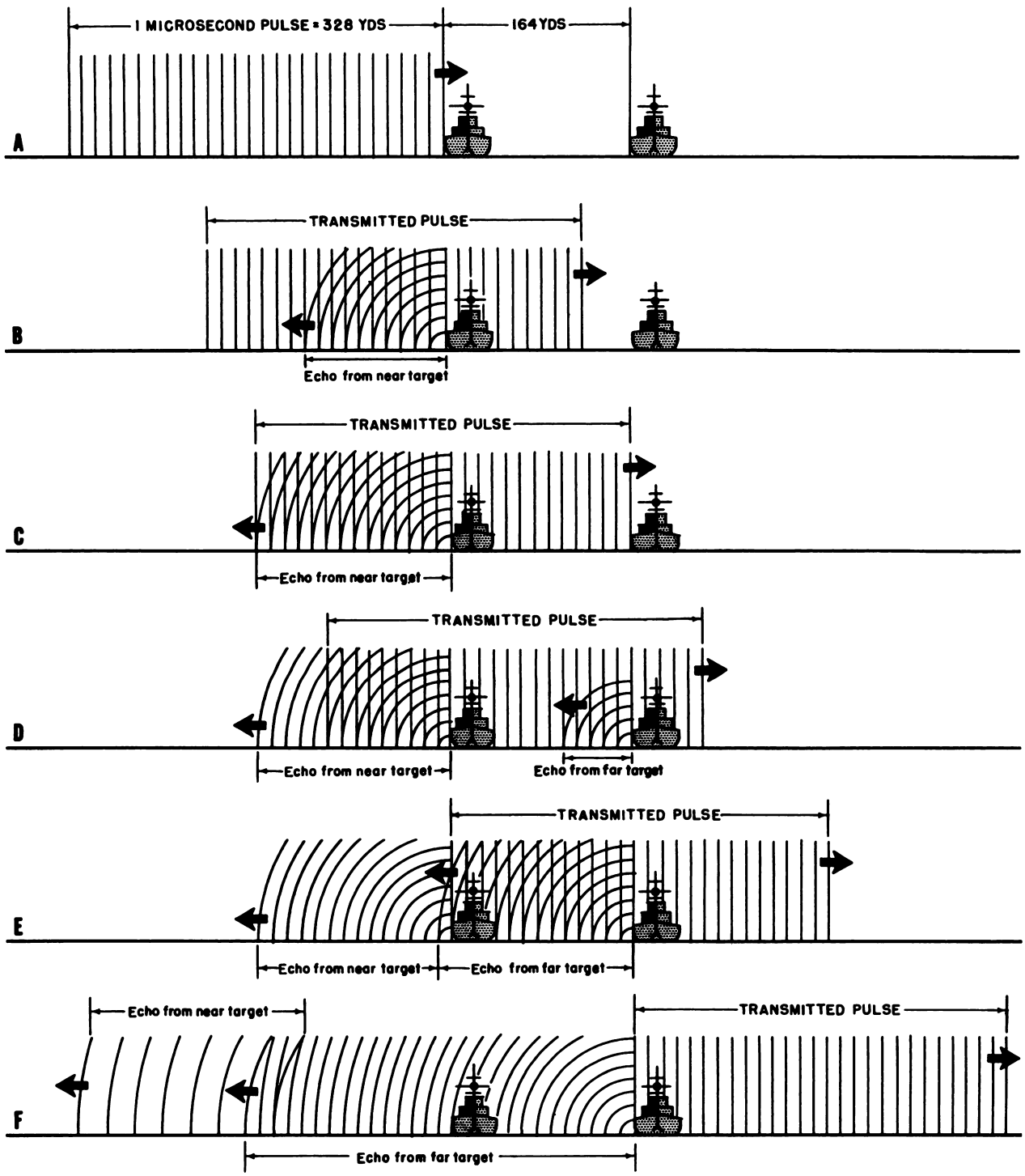

Figure 9-2.—Minimum target separation required for range resolution.

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traveling back toward the radar from both targets, and in part E, reflection is completed at the near target. Notice that at this time the leading edge of the echo from the far target has returned as far as the near target, so that it coincides with the trailing edge of the first echo. In part F, reflection is completed from both targets, and some of the transmitted pulse continues beyond them, while an echo of twice the normal width returns toward the radar. When the echoes reach the antenna, energy is delivered to the set during a period of 2 microseconds, so that a single wide pip shows on the scope.

Since energy is reflected from the target for the duration of the transmitted pulse, even a flat piece of sheet iron will cause an echo to appear to be 164 yards wide on the scope, provided the pulse duration is 1 microsecond. Thus, the echo from any target will appear, on the scope, to have a width in yards at least equal to 164 yards per microsecond times the pulse duration in microseconds. Ideally, then, the minimum separation between two targets that will permit the scope to resolve their echoes into two distinct pips is the range represented by the duration of the transmitted pulse.

RECEIVER GAIN

Range resolution can be improved by proper adjustment of the gain control. It is difficult to determine composition from a pip that is at saturation. Figure 9-3 shows the effect the receiver gain has on range resolution. When at saturation point, the pip will be square on top on the A-scope, and it will look like a blob of light on the PPI. By reducing the receiver gain the proper amount, it is possible to count the spikes on the A-scope and see individual pips on the PPI. Each spike represents a separate target. After using the gain control to obtain composition, do not leave the gain reduced, because you may miss small targets.

RANGE SCALE

Another factor to be considered when determining composition is the range scale used. On a long range scale, a separation of a few hundred yards will not be apparent, and two pips close together will seem to merge into one. To aid in separating these targets, use the shortest range possible and adjust the receiver gain as necessary. Sometimes, if targets that are close together can be displayed on a short range scale, as on an expanded sweep on an A-scope, or off-centered on a PPI, the small separation will be visible.

CRT SPOT SIZE

Theoretically, the electron beam in a cathode ray tube can be focused to a point of light. Actually, the point cannot be focused to such a small spot. Thus, the range separation required for resolution is increased because the indication on the screen is not well defined. In addition, there is a small amount of fringing on some cathode

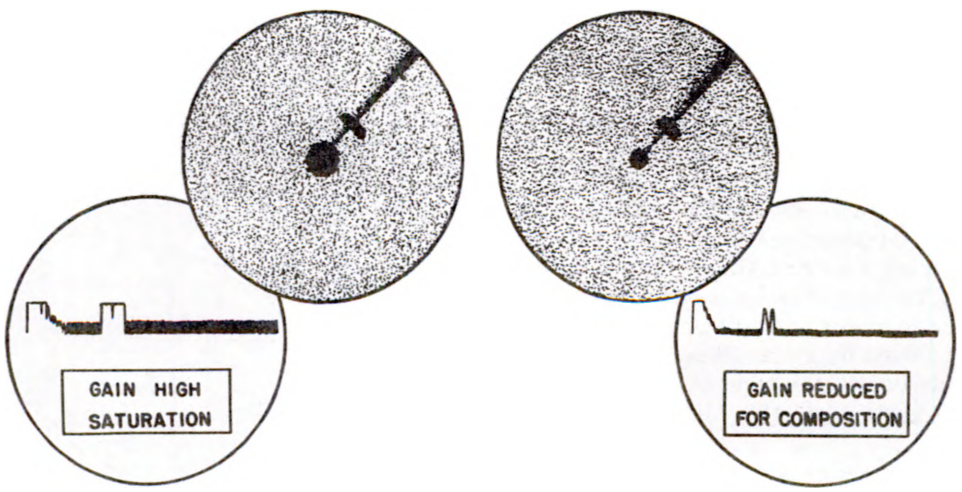

Figure 9-3.—Effect of receiver gain on range resolution.

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ray tubes causing the edges of the spot to be hazy. In general, large CRT's do not permit much improvement in definition of the pattern because the spot size increases almost in proportion to the tube size. In fact, the spot on some of the larger PPI tubes is proportionately larger than on smaller tubes.

PHYSICAL SIZE OF CRT

The physical size of the indicator tube has a definite effect on the range resolution of a radar, as you learned in chapter 7.

RELIABILITY OF RADAR RANGES

Because the radar operator cannot recognize the target on which he is ranging by any means other than interpreting the pattern that he sees on the scope, it is possible for him to range on the wrong object. This weakness opens the way to the use of certain deceptive countermeasures by the enemy. With a properly functioning CIC, however, and an adequate system of displaying and indicating targets to gunnery, mistakes of this sort can be eliminated or at least reduced considerably. The lookouts must be used to the maximum in identifying contacts that are within visual range. You, as a radar operator, can help keep identification errors to a minimum by a thorough knowledge of scope interpretation and proper use of the controls.

FACTORS AFFECTING BEARING ACCURACY

If radar could be used only on a single target, one all by itself, either stopped or moving slowly, accurate bearings could be measured easily. When targets move fast, it is difficult to keep the radar beam aimed properly, and therefore impossible to obtain complete accuracy from the radar. Several targets close together may return echoes that radar cannot resolve, thus preventing the determination of accurate bearings on any single target within a group. When the target is by itself and not moving too fast, the accuracy with which its bearings can be determined by radar depends on the width of the antenna beam, the type of scope on which the echoes appear, and the size of the target.

HORIZONTAL BEAM WIDTH

The more narrow the horizontal beam width, the more accurate the bearing determination of the radar. The horizontal beam width is specified in degrees between the half-power points in the radiation pattern. Half-power points are those points at which the transmitted power is half the value of that radiated along the lobe center of maximum energy sent out.

Increasing Bearing Accuracy

Lobe switching and certain types of scans are used to increase the bearing accuracy so that the target bearing can be determined within 0.03° in some fire control radars. Since general-purpose radars do not use lobe switching or other special scans, these scans will not be considered in this chapter. For additional information concerning these special scans, consult NWIP 31-6.

It's Up To You

The accuracy of the bearing you report depends upon how accurately you can estimate the exact instant the height of the pip is maximum, or your ability to center the electronic or mechanical cursor on the pip.

When using the A-scope, the pip will be maximum height if the center of the antenna lobe points directly at the target.

Shape Of Lobe

The difficulty experienced in trying to determine when the pip reaches a maximum can be gained by observing figure 9-4. Notice that the front, or nose, of the lobe is flat and the slope is gradual, but as you approach the sides of the lobe, the slope of the curve becomes steep.

Effect On Size Of Pip

How does this affect the size of the pip received by the radar? Examine figure 9-4 step by

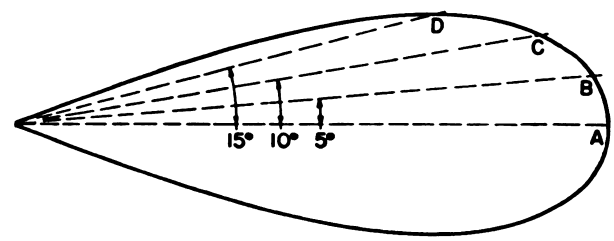

Figure 9-4.—Edge of lobe gives most accurate bearing indication.

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step and see how the formation of the lobe determines the type of pip received. Targets located on the bearings A, B, C, and D all give echo return. Consider what happens when the lobe moves upward (to the left). There will be very little difference in the return when the center of the lobe crosses B. The reason for this is that B is only slightly closer to the receiver, and the operator will have to watch the scope closely to see any difference in the size of the pip. From B to C the lobe begins its curve and, although the angle between B and C is only 5°, the same as between A and B, the size of the pip will be much larger because C is so much closer to the receiver. As the lobe moves further to the left, this difference is increased even more as the center of the lobe crosses D.

Centering Lobe On Target

The purpose of this discussion is to impress upon you the importance of centering your lobe on the target. As indicated, the difference in pip size between A and B is very small. But for purposes of bearing indication, there is a difference of 5° in location. This is the same degree difference as between C and D, where there is a relatively large difference in pip return.

MAXIMUM AND MINIMUM PIPS

Some place near point D in figure 9-4, the pip will fade to a minimum size, and if the lobe is moved another degree or two to starboard, the pip will disappear completely. The point where the pip is minimum and can just be seen is very sharp, and is a number of degrees from the center. On a lobe that is uniform in shape, this angle is equal both to the port and starboard sides of the center. It must be pointed out also that each radar antenna has its own characteristic (beam width) between the maximum and minimum pips. The beam width is not the same for all antennas.

BEARING DETERMINATION USING MINIMUM PIPS

You may use the minimum target echo pips to increase the accuracy of bearing determination, provided you know the size of the angle between the maximum pip position.

Figure 9-5 shows that the angle between the maximum and minimum pips is 15°. In view A, the lobe has been moved to the left of the target. The bearing indication for the minimum pip given by the center of the lobe is 045°.

In figure 9-5, view C, the lobe is to the right of the target. The bearing indication given is 075° for the minimum pip.

Since the first bearing reading was 15° too small, and the second reading was 15° too large, the correct bearing lies halfway between; that is, it is the average of the two:

$$\frac{045 + 075}{2} = 060.$$

Thus the actual bearing of the target is 060°.

Slow But Sure

This type of bearing determination is accurate but extremely slow. Therefore it is not used except for accurate tracking against slow-moving targets. It requires two readings, and you will have to obtain an average before you can report the bearing.

Maximum Pip Method

To determine the bearing of a target by the maximum echo method is rather simple. Adjusting the antenna until the largest pip appears on the A-scope or the brightest spot appears on the PPI-scope will give the direction of the target.

Special Occasions

The methods of obtaining bearings described are used only during special occasions. Normally, the bearings are obtained when the antenna is rotating. The electronic cursor or mechanical cursor is adjusted until the cursor crosses through the center of the pip or crosses any part of a target whose bearing you are taking.

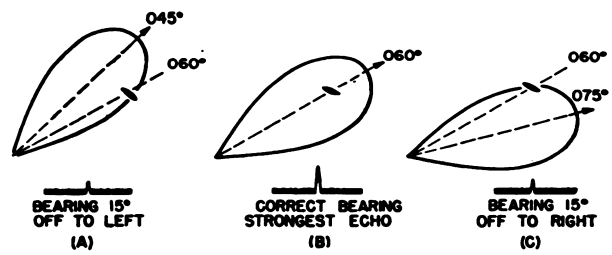

Figure 9-5.—Bearing determination using minimum echo.

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FACTORS AFFECTING BEARING RESOLUTION

When two targets are separated by a small angular distance, the bearing of either target is more difficult to determine accurately.

EFFECT OF BEAM WIDTH

The effective horizontal beam width of the radar determines the bearing resolution. This is not a constant quantity, because it is also affected by the receiver gain, and the size and range of the target.

Let's consider what happens to a single target. It is not easy to judge the size of targets from the size of the pip shown on the PPI-scope. Visualize a radar with a horizontal beam width of 10°. The trace on the PPI-scope represents the center of that beam. If a target is anywhere within the beam, a pip will appear on the trace, and will seem to indicate a target at the center of the beam. The pip, therefore, appears to be 10° wider than the target. This is because the pip begins to show as soon as the leading edge of the beam hits the target, and continues showing until the trailing edge of the beam leaves the target and is 5° to the right of the target. (See fig. 9-6.) In the pip seen on the scope, the left 5° and the right 5° are false indications. Therefore, the bearing is read to the center of the pip.

This discussion of the effect of beam width on bearing resolution further explains how beam width affects bearing accuracy.

Judging Size of Target

This additional 10° makes the determination of the target size difficult when judging from the length of the pip. Suppose that a destroyer is picked up at 10 miles. A destroyer is about 300 feet long; at 10 miles it is 0.25° wide. It would appear on the scope as a target 10.25° wide (10° beam width plus 0.25° target width). An aircraft carrier at the same distance is actually 0.75° wide, since it is about 900 feet long. Its pip would, therefore, be about 10° plus 0.75° or 10.75° wide. Judging by pip size, it would be almost impossible to tell the difference between two pips separated by only 0.5°. On the other hand, a convoy of ships extending for a mile would produce a pip of about 15°. The reflection of the convoy would appear bigger than any single ship. (See fig. 9-7.)

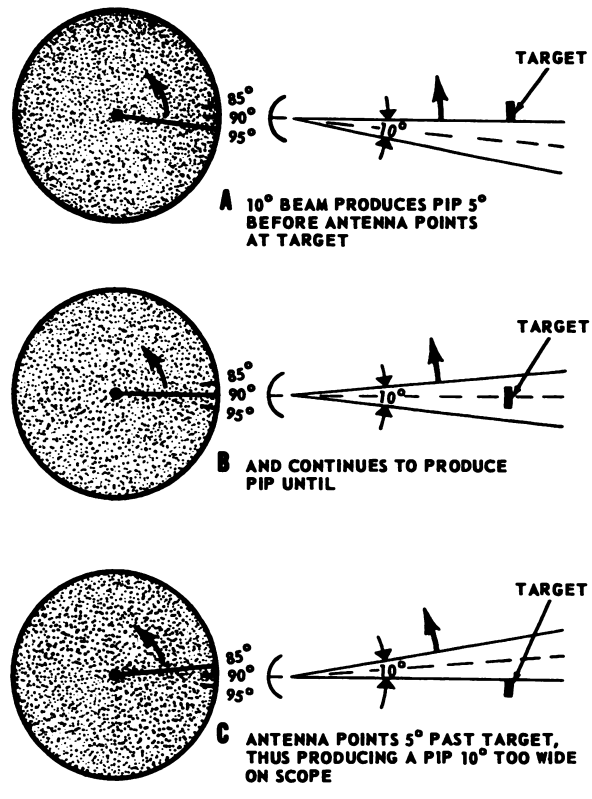

Figure 9-6.—Target pip is always widened on the scope an amount equal to beam width.

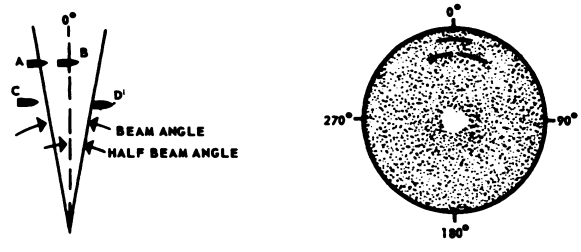

Figure 9-7.—Bearing resolution on PPI presentation.

Separation of Targets

A target's indication on the scope is increased angularly an amount equal to the beam width—each end is extended one-half the beam width. Two targets at the same range, to be separated on the scope, must be more than one beam width apart.

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Effect of Range

The necessary distance between the two targets depends upon their range, because the length included within a 10° beam width differs at various ranges. At 10 miles, for example, 10° is equal to 1.75 miles; therefore, two targets would have to be separated by more than this distance to appear as two distinct pips. At 5 miles, 10° is equal to 0.8 mile and the targets would appear as distinct pips if they were 1 mile apart. This is why a convoy of ships at a distance appears as a single large pip. On approaching it, however, it gradually breaks up into separate pips.

Land Mass Distortion

Reviewing figure 8-2, you will see that beam width distorts land mass shorelines on the scope the same way. The individual reflection portions are stretched 5° in each direction. The beginning and ending shorelines appear extended 5° farther into the sea. A peninsula appears 10° wider than it actually is, and a small cove may be blotted out completely on the scope by the extension of reflections from both its banks into the center. A small lake or river may also be completely blotted, although frequently the far banks will be steep enough to give identifiable echoes, even if the width is too narrow to be distinguished. In all cases the distortion is decreased as the ship approaches. Proper use of the receiver gain control will help in bringing out the actual shoreline.

Since the bearing resolution is determined by the horizontal beam width, a radar with a narrow beam width provides better bearing resolution than one with a wide beam.

RECEIVER GAIN

The bearing resolution, as pointed out earlier, can be made better by proper adjustment of the gain control. Operation of the gain control is the same as for range resolution.

FACTORS AFFECTING ALTITUDE DETERMINATION ACCURACY

The factors that affect altitude determination accuracy are essentially the same as for range accuracy and bearing accuracy except in the vertical plane.

VERTICAL BEAM WIDTH

The more narrow the vertical beam width, the greater the accuracy of altitude determination.

TYPE OF SCAN

The type of antenna scan used affects the accuracy of altitude determination. Spiral, lobe switching, and conical scan afford greater accuracy.

INDICATOR

The type of presentation and the alignment of the indicator with the antenna contribute to the accuracy of altitude determination.

RANGE OF TARGET

The accuracy of altitude determination increases as the range to the target decreases.

FACTORS AFFECTING ALTITUDE RESOLUTION

The same factors which affect bearing resolution affect altitude resolution when applied to the vertical beam dimensions.

RELIABILITY OF ALTITUDE DETERMINATION

Since the radar can detect airplanes at long ranges, it can be very useful in controlling the interception of attacking aircraft. The radar, however, must determine not only the range and bearing of attacking groups, but also the altitude. For ease in controlling an interception, the radar should be able to indicate the relative altitude of two groups of planes within 1000 feet if the interception takes place during good visibility, and within about 500 feet at night or under conditions of poor visibility. When it is considered that aircraft are often detected at distances over 100 miles, it is evident that altitude accuracy within 500 to 1000 feet requires extremely precise measurement.

ALTITUDE ESTIMATIONS

The altitude estimated by noting the range at which the target is first detected on air-search radar is far from reliable. Such data should be regarded merely as guesswork, because reduced radar performance or evasive action by the target can cause this information to be misleading. Therefore, this estimate should be used only to coach the altitude-determining equipment onto the target. As mentioned previously, the best

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method of checking the accuracy of the altitude is to compare the altitude of friendly planes with that of bogies, if possible.

ACCURACY AT LONG RANGE

At long ranges, beyond 100 miles, neither the height-finding radar altitudes nor the fade chart estimations are very accurate. Generally the altitude determined by estimation from fade charts have been found more reliable. This is caused both by limitation on the accuracy of measuring position angle, and by the fact that at long ranges the position angle of a target will be quite small.

COACHING ONTO TARGET

The more narrow the vertical beam width of the height-finding radar, the more accurate the altitude determination. It is rather difficult, however, for a narrow beam to detect a target, particularly if the altitude is not known. This is why most ships, to determine altitude, use a radar control officer (RCO) to coach the height-finding operator onto the target detected by the air-search radar. To gain the full accuracy of the height-finding equipment, the antenna of the height finder must be stopped on the target for some time. When an interception is in progress, this means that the height-finder radar cannot be used for all-round searching if dependable altitudes are to be obtained. Many ships, however, do not use the height finder in this manner. They sacrifice altitude accuracy by using search capabilities to detect other targets and in so doing gaining only their approximate altitudes. The procedure you will use must be specified by your CIC officer.

LIMITATIONS IMPOSED ON RADAR BY EXTERNAL FACTORS

As a Radarman you will see the word "propagation" used in many books and hear it often. Propagation means the travel of electromagnetic waves, as sent from the radar antenna, through a medium. Dissemination of radar waves is another way of expressing it. The medium through which these waves travel is called ETHER. Ether, as scientists use the word, is what remains in space when all substance or matter, as we know it, has been removed. This is the medium that transmits radar waves through space.

It is assumed that radar waves travel along perfectly straight paths. The curvature of the earth prevents these straight-traveling waves from striking objects that are beyond the horizon. If the height of the antenna is increased, the point at which the lowest radiated wave will come to the curve of the earth, that is, the horizon, is extended. An object beyond the horizon can be seen if it is high enough so that the wave can strike it.

Radar waves, like light waves, must pass through the atmosphere to travel from one place to another. The characteristics of the medium through which the waves pass affect the manner of their transmission. Thus, although it is sometimes assumed that both light and radar waves follow perfectly straight paths, the properties of the atmosphere are such that the waves are made to follow curved paths. One very common effect of the bending that light waves experience in passing through the atmosphere is apparent at sunrise and sunset. At this time the sun is very low, so that none of its light would be visible if the rays followed straight paths; but, because the red parts of the light are bent down to earth, the sky is brightly colored.

The propagation of radar waves, then, is affected by (1) the composition of the atmosphere which controls the amount of bending (refraction) that the waves experience in their passage; (2) the diffraction that bends the waves over the horizon to some extent; and (3) the reflection of the radar waves from the surface of the sea. Other factors that affect propagation of radar pulses are the antenna pattern, the attenuation of the radar waves in their passage through the atmosphere, and the size and character of the target that the pulses strike.

The Kennelly-Heaviside layers, which are in the ionosphere 30 to 200 miles above the earth, reflect long wave radio energy back to earth, and so exert considerable effect on the propagation of frequencies below 40 megacycles. However, the Kennelly-Heaviside layers are penetrated by the high frequencies used in radar and most VHF and UHF communications, so that these waves are not returned to earth. The Kennelly-Heaviside layers, therefore, do not appreciably affect the propagation of radar pulses.

REFRACTION

The bending of radio or radar waves due to a change in the density of the medium through

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which they are passing is termed refraction. The measure of the bending that occurs is indicated by the index of refraction from one substance to another. The density of the atmosphere changes at a gradual and continuous rate, therefore the index of refraction changes gradually with increased height. Radar waves bend more than light waves, resulting in a horizon distance 1.25 times the optical horizon.

REFLECTION OF RADAR WAVES FROM THE SEA

Radar waves which are reflected from the surface of the sea may arrive at a point in space either in phase or out of phase with the direct wave. Direct and reflected waves arriving at a point in space out of phase result in fade areas, due to cancellation of the effective signal strength.

DIFFRACTION

The means by which a wave curves around the edges of an object (such as a small island) and penetrates into the shadow region behind the land mass is called diffraction. The diffraction effect permits some of the radar energy to enter the shadow region below the radar horizon. Low-frequency waves are affected more than high-frequency waves by this phenomenon.

ATTENUATION OF TRANSMITTED PULSE

Attenuation of the transmitted pulse, due to normal scattering of the energy, results in a decrease in the ability of the radar to produce strong echoes at long ranges.

Gases and water vapor that make up the atmosphere absorb energy from the transmitted pulse. The higher the frequency, the greater the absorption of energy. Frequencies below 3000 megacycles are not appreciably attenuated, while frequencies above 10,000 megacycles are highly attenuated.

TYPE OF TARGET

The amount of energy reflected back to the radar is proportional to the size of the reflection area of the target, as long as the target is large compared to the wavelength of the transmitted energy. Only high-frequency radars will effectively detect small targets such as periscopes. Conductive materials will reflect stronger signals than nonconductive materials. Since radar targets are composed of variously oriented surfaces and corners, the distances between the radar and the various parts of the target will be slightly different. The best aspect is one with a reflecting surface at an angle of 90° to the radar antenna. If not at an angle of 90° the signal components returned by the many parts of the target may be out of phase by the time the echo returns to the radar, resulting in fluctuating target pips. Because aircraft targets change aspect more rapidly than surface targets, pips from aircraft fluctuate more rapidly and hence more noticeably.

TRAPPING

The temperature and the moisture content of the atmosphere normally decrease with height above the surface of the earth. Under certain conditions, the temperature may first increase with height and then begin to decrease. Such a situation is called temperature inversion. More important, the moisture content may decrease more rapidly with height just above the sea. This effect is called moisture lapse. Either temperature inversion or moisture lapse, alone or in combination, may produce a great change in the index of refraction of the lowest few hundred feet of the atmosphere, resulting in greater bending of the radar waves. This may greatly extend or reduce the radar horizon, depending on the direction in which the radar waves are bent. The height of the radar antenna with respect to the "duct" formed by this strange occurrence is of much importance in controlling the effects of trapping.

AREAS WHERE TRAPPING OCCURS

Although trapping conditions can happen any place in the world, the climate and weather in some areas make their occurrence more likely. In some parts of the world, particularly those having a monsoonal climate, variation in the degree of trapping is mainly seasonal, and great changes from day to day may not take place. In other parts of the world, especially those in which low barometric pressure areas recur often, the extent of nonstandard propagation conditions varies considerably from day to day, even during the season when they are most common.

Even though the geographical and seasonal aspects of trapping are not yet so firmly established that a map of the world can be drawn with

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trapping areas reliably outlined, it is possible to make a general summary.

Atlantic Coast of the United States

Trapping is common in summer along the northern part of the coast, while in the Florida region the seasonal trend is the reverse, with a maximum in the winter season.

Western Europe

There is a pronounced maximum of trapping conditions in the summer months on the eastern side of the Atlantic, around the British Isles, and in the North Sea.

Mediterranean Region

Available reports indicate that the seasonal variation is very marked, with trapping more or less the rule in summer, while conditions are approximately standard in winter. Trapping in the central Mediterranean area is caused by the flow of warm, dry air from the south, which moves across the sea and thus provides an excellent opportunity for the formation of ducts. In the winter, however, the climate in the central Mediterranean is more or less the same as Atlantic conditions, therefore not favorable for duct formation.

Arabian Sea

The dominating meteorological factor in this region is the southwest monsoon, which blows from early June to mid-September and covers the whole Arabian Sea with moist equatorial air up to considerable heights. When this meteorological situation is fully developed, no occurrence of trapping is to be expected. During the dry season, on the other hand, conditions are different. Trapping is then the rule rather than the exception, and on some occasions extremely long ranges (up to 1500 miles) have been observed on P-band radar on fixed targets.

When the southwest monsoon sets in early in June, trapping disappears on the Indian side of the Arabian Sea. Along the western coasts, however, conditions favoring trapping may still linger. The Strait of Hormuz (Persian Gulf) is particularly interesting as the monsoon there has to contend against the shamal (a northwesterly wind over Mesopotamia and the Persian Gulf from the north. The Strait itself lies at the boundary between the two wind systems, and a front is formed with the warm, dry shamal on top and the colder, humid monsoon underneath. Conditions are consequently favorable to the formation of an extensive duct, which is of great importance to radar operation in the Strait of Hormuz.

Bay of Bengal

The seasonal trend of trapping conditions is the same as in the Arabian Sea, with standard conditions during the summer southwest monsoon, while trapping is found during the dry season.

Pacific Ocean

Frequent occurrences of trapping around Guadalcanal, the east coast of Australia, and around New Guinea and Korea have been experienced. Observations along the Pacific coast of the United States indicate frequent trapping, but no clear indication of its seasonal trend is available. The meteorological conditions in the Yellow Sea and the Sea of Japan, including the island of Honshu, are approximately like those off the northeastern coast of the United States. Therefore, trapping in this area should be common in the summer. Conditions in the South China Sea approximate those off the southeastern coast of the United States only during the winter months, when trapping can be expected. During the rest of the year, the Asiatic monsoon modifies the climate in this area, but no information is available on the prevalence of trapping during this time. The trade winds in the Pacific quite generally lead to the formation of rather low ducts over the open ocean.

OPERATIONAL EFFECTS OF TRAPPING

Because of the effect of trapping on communications and the operation of radar equipment, a knowledge of trapping is required.

Effect on Radar Performance

A serious operational consequence of trapping is that it misleads radar operators regarding the over-all performance of the equipment. Long-range echoes caused by trapping have frequently been assumed to indicate good condition of the equipment when precisely the opposite may be the case.

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The changing propagation conditions that radar waves can encounter, then, can have considerable effect on radar performance. To summarize, trapping may affect radar in the following ways:

1. Increase the range of detection for surface vessels and airplanes flying within a duct.
2. Reduce the range of detection for airplanes flying just above a duct.
3. Reduce the range of detection for surface vessels and low-flying planes in some types of foggy weather.
4. Modify the height at which airplanes should fly to avoid detection by enemy radar.
5. Cause errors in height finding for targets below position angles of 1°.
6. Increase the extent of clutter from sea return, and thus reduce the operational efficiency.
7. Increase the range to which a navigational aid can be effective.
8. Increase the range at which radar signals can be heard.
9. Modify the degree of jamming either suffered or inflicted.

Important aspects of the effect of weather on radar operation, other than signal propagation, are covered in another chapter.

QUIZ

1. What factor is considered the most important in affecting the over-all efficiency of radar equipment?
2. What effect does the pulse repetition rate have on the range detection of a radar?
3. What type of material returns the best reflections?
4. How does the antenna rotation rate affect the radar detection range?
5. What factor primarily determines the minimum range at which the radar can detect targets?
6. Name some factors that affect the range accuracy of a radar.
7. Define range resolution.
8. What is the major factor determining a radar's bearing resolution?
9. Using a radar with a 10° antenna beam width, how would a pip appear on the PPI-scope on a convoy extending a width of a mile at a distance of 10 miles?
10. What control may help to discriminate between two targets at the same range but slightly different bearing?
11. What is the best method of determining the height-finding radar's altitude information?
12. Name three factors that affect radar propagation.
13. Why must a Radarman have a knowledge of the effect trapping has on radar performance?
14. Does trapping always give good radar detection results?

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CHAPTER 10

PIPOLOGY

ECHO INTERPRETATION

Echo interpretation is the study and analysis of radar echoes. This study includes the determination of bearing, range, altitude, course, and speed and analysis of the pip to discover whether it is one object or more than one. COMPOSITION is the term used in the analysis of pips to designate how many targets, types, and if possible identification of targets.

The amount of reliable information that can be obtained from any radar relies to a great extent on the skill of the operator. It is difficult to operate a radar with a high degree of accuracy under all conditions. An operator, therefore, must have intelligence, imagination, skill, great powers of concentration, and intense interest in his work, if radar is to be used for maximum results. To become proficient, the operator must practice continually.

The more the operator is able to understand about his radar and about the tactical situations in which it is used, the better the results will be.

Many strange contacts have been made with radar which have been given names such as phantoms, pixies, gremlins, and the like, for want of a reasonable explanation. If the operator understands the limitation of his radar and knows the position of nearby friendly ships, he will be able to recognize all types of false targets.

Long experience in watching a radarscope enables the operator to notice many things in an echo that may not be noticable to a less experienced man. Experience will permit an operator to judge the size and type of an object causing an echo. For example, the pip from several planes in a group is usually distinguishable from that returned from a single plane so that he can estimate the number of planes in the group. An unskilled operator can determine only range and bearing, and perhaps that will be unreliable at times; a proficient operator sees much more than just the normal range and bearing measurements.

Usually a skilled operator can detect a target at a greater distance than an unskilled operator. This ability results from close observation of the scope and a feeling for the appearance of echoes that, to the untrained eye, are lost in the "grass."

A properly trained operator will measure each range in exactly the same way so that his personal error is small and constant. As a result, the ranges and bearings obtained by a trained operator will be more consistent and more reliable than those obtained by an unskilled operator. The skill and ease developed by constant practice will also enable an operator to measure a range and bearing more quickly.

THE IMPORTANCE OF SPEED

It is important for you not only to recognize the target, but to do so in the shortest possible time. Some of the advantages of speed in recognition are that:

1. It aids the plotters in assembling information;
2. It speeds up evaluations and decisions;
3. It gives gunnery personnel more time to get on target;
4. It adds to the overall efficiency of the radar watch.

PIP CHARACTERISTICS

Pips are of various types and each type lends itself to interpretation. In general, there are four characteristics of pips that will give you useful information:

1. Size of pip.
2. Shape of pip.
3. Bobbing or fluctuating movement of pip.
4. Movement in range and bearing.

The A-scope is most useful for observing the size and fluctuation of a pip. However, since an A-scope is not readily available at all times to the operator, a PPI may be used, but requires

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a higher degree of skill. An expanded or short range A-scope may be used for observing shape of the pip, while movement is more readily apparent on the PPI. This chapter takes up pip characteristics in some detail as an aid in interpreting the things you are likely to see on a radarscope.

FRIEND OR FOE

The first thing to do is to determine whether the target is a friend or foe. IFF is described fully in *Radarman 3 & 2, Vol. 2.* The method to be followed in challenging a new target depends on the DOCTRINES (instructions) and practices developed for your ship. Ask your supervisor beforehand about the procedure for your ship and learn it thoroughly. Once a contact is made on the radarscope, action is required immediately and you don't have time to then ask questions.

FOLLOW THE BOUNCING PIP

Having found the friend or foe status of the contact, the next step is to find the rapidity and extent of the fluctuation of the echo. Consider the height of the echo if using the A-scope, or the brightness and largeness if using the PPI-scope remembering the effect of range and fades. Then note the depth or thickness of the echo. If the echo is saturated, reduce the gain. Look at the top and sides of the echo for any indication of two bumps, or many little bumps, which would indicate more than one target. At what speed is the echo moving?

Watch the pip closely to see how much information you can obtain from its shape, movement, and size.

DETERMINING TARGET SIZE

First of all, on what does the size of the pip depend? The answer is, unfortunately, on a number of things, the most important being:

1. Range of the target.
2. Size of the target.
3. Height of antenna (especially where surface contacts are concerned).
4. Height of the target.
5. Whether the target is bow or broadside (target angle).
6. Atmospheric conditions.
7. Material composition of the target.
8. Correctness of tuning.
9. Material condition of the radar set.

Due to the many factors involved, it is not possible to determine the exact size of the target in every case, but you can always make a close estimate.

This much you do know: If you have a large and small target at the same range, the large target will produce the larger pip, all other factors being equal. If you detect a group of ships approaching, the PPI picture may appear as in figure 9-7. Thus, the only positive thing that size of pip will tell you is the relative size of various targets at the same range.

RANGE OF FIRST PICK-UP

One of the best ways of judging the size of a target is to note the range at which it is first picked up.

At a given range an object has to be a certain size before it will return an echo that can be seen on the scope. This means that a particular size of ship or aircraft first becomes visible on the scope at a definite range. With aircraft this initial pick-up range will vary with the altitude of the aircraft (assuming that you and your set are operating at top efficiency).

The echoes come first from the masts and superstructure of a ship. The size of the echo is about the same regardless of the course or position of the ship. Since large ships have large and high superstructures, these will be observed first. Smaller, low-lying vessels, such as surfaced submarines, will probably appear only at short range.

Each radar will have its own characteristic range at which a target of a certain type (air or surface) will appear. Once you learn the capabilities of the radar that you are operating, the approximate size can be estimated by echo strength, range, and target angle. Target angle can be obtained by plotting the contact for a few minutes.

TARGET ANGLE

When the radar beam strikes the hull of a ship target angle is a very important consideration in determining the size of the target. Target angle is the relative bearing of your ship as seen from the target ship.

At 90 or 270° target angles a special reflection takes place. When a pulse strikes a ship with two plane reflecting surfaces that are at right angles (such as the side of a ship and the water surface), a corner reflector is made. The value of a corner reflector is that

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any pulse that can enter the corner is reflected out of the corner along a path parallel to the in-coming pulse. This in turn gives a signal that is very strong. Thus, a ship that is broadside to you will give a larger echo than one that is heading directly toward or away from you, because there is more surface from which to reflect, plus the corner reflector effect. So, if the target angle is near 90 or 270° the target is broadside to you and the echo will be larger than if the same ship had a target angle of 000 or 180°.

If there is either a sudden increase or decrease in the size of the pip, the target has probably changed course. Report all sudden changes immediately. They are important.

An aircraft will also reflect more energy if it is broadside. However, there will be no corner effect unless there are parts of the plane that form corner reflectors. When a plane is flying directly at you, the pip is weaker than when broadside. Therefore, when a plane is maneuvering, its pip will almost fade completely at times, then become very bright.

SPEED OF TARGET

You would not expect an aircraft carrier to make 100 knots or an airplane to fly at 20 knots. The speed of movement will tell you much about the probable nature of a target.

Keep in mind, however, that the speed of your own ship affects the relative speed of the target if it is a surface contact. In event a land target is picked up on the scope, it will show an apparent speed the same as own ship's speed and a reciprocal course to your course.

ONE PIP AREAS

To enable you to get a better understanding of resolutions, let us consider the effect of both bearing and range resolution at the same time, instead of one at a time, as we did in chapter 9.

The diagrams in figure 10-1 demonstrate that on the same radar, A-scopes are superior to PPI's for observing range and bearing resolution. They show the size and shape of an area in which no resolution is possible. These are called "one pip areas." Notice that the range resolution does not vary with range (as long as the same range scale is used) and the width of the one pip area increases with range. The bearing resolution expressed as an angle does not vary with range, but the actual width or intercept angle does increase. Therefore, one pip area is narrow angularly at short range, and wide at long range. These situations are due to and depend on the horizontal beam of the radar in use.

For any given range there will be a one pip area of a definite size and shape. If you detect a group of ships at that same range, they will give only one pip (no matter how many ships there are) provided all the ships in the group can be completely fitted into this area.

Examine figure 10-1 closely. The group of ships, when at long range, fits just inside the one pip area on the PPI and as a result only one pip will be seen on that indicator. However, two pips will be seen on the A-scope because the one pip area of the A-scope is small and cannot contain all of the pip. In this case targets A and D will show as one pip that can be resolved in range from the other pip formed by targets B

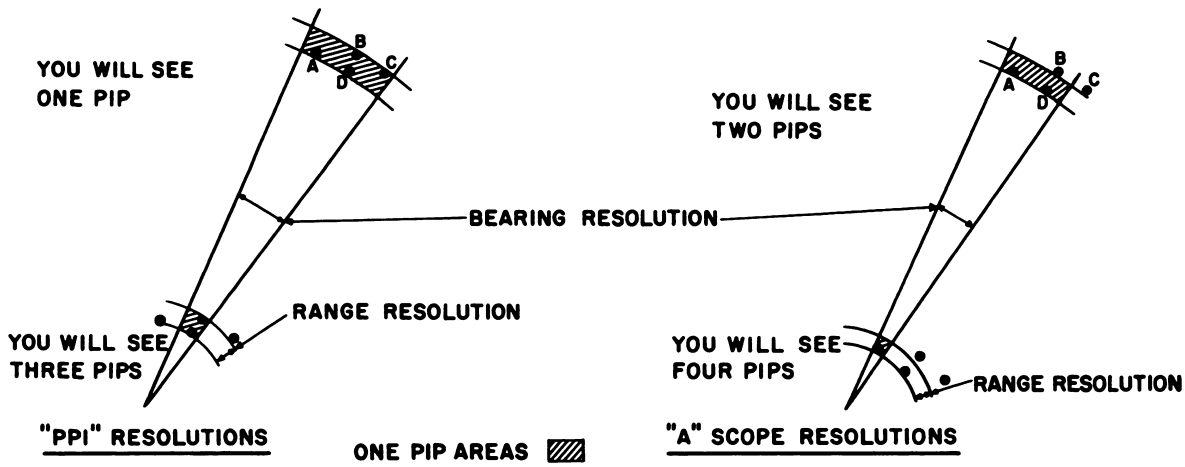

Figure 10-1.—One pip areas.

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and C. Thus, by using the A-scope you can see two pips instead of the one visible on the PPI.

After the group of ships has closed to a shorter range, you will be able to tell much more about the composition. Even the PPI will then show three pips. Since B and D can be enclosed by the one pip area, they will give only one pip. When B and D are in the one pip area, neither A nor C can fit into it, and therefore they will be resolved and three contacts will be seen: A, B-D, and C. Observe how small the A-scope one pip is at this range. Only one ship at a time can be enclosed by it, with the result that four separate contacts can be recognized. In other words, each contact can be resolved from the next, in both range and bearing.

You can see that the smaller the area occupied by a group of ships, the closer you have to approach the group in order to tell, by radar, how many ships are in it. Finally, you realize the importance of checking composition frequently at close ranges. At any time one pip may become several. Although we have used surface targets in our discussion, it would be the same for air targets.

ESTIMATING THE NUMBER OF PLANES

On the A-scope an echo from a single aircraft will show up as a pip which bounces wildly and erratically. An echo from a large plane will bounce less erratically than a pip from a small one, just as a pip from a large ship will bounce less than a pip from a small ship.

Two planes usually give a wider pip in range, or bearing, and the pip will rise and fall more steadily. The echo of three or more planes in formation will have an uneven, jigging motion, distinctly different from two planes, in that it is not regular. The echo will not decrease nearly to zero, but will remain close to maximum height.

The number of aircraft in a formation can be roughly estimated by counting the individual pips and multiplying the result by three. Remember that this is just an approximation.

On the PPI you must track own and other combat air patrols on the face of the scope and know their location at all times. You can follow movement of strike aircraft, sweeps, and searches and this will keep you up to date on the current air situation. When a bogey or unidentified aircraft appears on the scope, you have an instantaneous and accurate position of it. By observing the size, shape, and form of the pip, you can estimate the number in the flight.

An echo returned from a single medium-sized aircraft at a great distance will appear as a dim, thin strip of light on the PPI-scope. As the antenna rotates an echo will appear each time the beam sweeps across the plane. On one sweep the pip may appear dim and the next one a little brighter than the previous one. On the following sweep the pip may completely fade and remain in a fade for several sweeps. If you should stop the antenna on the plane and keep it trained there which is not a recommended procedure, the pip will fluctuate in brightness and produce a sort of blinking effect, caused by becoming bright at times and then dim.

Two planes or a single large aircraft are usually detected at a greater distance because of the increased reflective surfaces. Pips from these contacts will ordinarily be brighter than a pip from a smaller contact. The brightness fluctuation is at a slower rate with less fading than smaller targets.

A group of aircraft flying in a tight formation may appear as a single large aircraft; but if the formation is spread out, or if there are a large number of planes, the pip will appear thicker in depth and width or may consist of several partially merged pips. Echoes from large groups of aircraft can be easily mistaken for weather because of the large area occupied on the scope. However, a few plots with a grease pencil will tell the difference. Echoes returned from large groups of planes rarely fade.

TYPES OF TRACKS

Two types of track are used: the continuous line or the dot method.

The continuous line method consists of placing a grease pencil mark at the inside center of the pip and drawing back a short line. On each successive sweep, this is repeated on the new pip. Always be sure to start at the new position of the target and to draw the line back to connect with the last position. If your grease pencil has a sharp point, a light, narrow, continuous line will result, showing clearly the track of the target.

If the dot method is used, the operation is similiar except that successive positions of the target are not joined. As a result, the back track appears as a line of dots. This method does not show course changes of the target quite as accurately as the continuous line method, but it does have the distinct advantage of showing changes

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in the target's speed. The dot method is the one generally used.

With either method, mark the target at every sweep, indicate a DR'd position with an X. Even though we have used an aircraft in the discussion of types of tracks, the same procedure is used for surface.

GENERAL HINTS ON COMPOSITION

Since air-search radars can detect surface targets, and surface-search radars can detect air targets, a few hints on recognition of these targets will be of value to you.

LAND TARGETS

Land targets can be usually determined by observing the following:

1. Not moving according to geographic plots. However, the contact moves on the radarscope because of motion of own ship.
2. Pip does not bob on the A-scope, as a moving target would. On the PPI the pip usually will remain at the same brightness.
3. Should be at expected positions.
4. Usually cover a greater area on the screen than other targets.
5. Separate pips do not move relative to one another.
6. Sandspits and smooth, clear beaches do not show up on radar at ranges beyond 1 or 2 miles because these targets have almost no area that can reflect energy back to the radar. Ranges determined from these targets are not reliable because when you think you are ranging to the beach you might be ranging on the surf. If waves are breaking over a sandbar on the beach, echoes may be returned from the surf. Waves may, however, break well out from the actual shore, so that ranging on the surf may be misleading when a radar position is being determined relative to the beach.
7. Mud flats and marshes generally reflect radar pulses only a little better than a sand spit. The weak echoes that are received at low tide disappear at high tide. Mangroves and other thick growth may produce a strong echo. Therefore, areas that are indicated as swamps on a chart may return either strong or weak echoes, depending on the density and size of the vegetation growing in the area.
8. When there are sand dunes covered with vegetation well back from a low, smooth beach, the apparent shoreline determined by radar will be the line of the dunes rather than the true shore. Under some conditions, sand dunes may return strong echo signals because the combination of the vertical surface of the vegetation and the horizontal beach may form a sort of corner reflector.
9. Lagoons and inland lakes generally show as blanks on a PPI-scope because the smooth water surface returns no energy to the radar antenna. In some cases, the sandbar or reef surrounding the lagoon may not show on the radar because it lies too low in the water.
10. Coral atolls and long chains of islands may produce long lines of echoes when the radar beam is directed perpendicular to the line of the islands. This is especially true when the islands are closely spaced since the spreading that results from the width of the radar beam causes the echoes to blend into continuous lines. When, however, the chain of islands is viewed lengthwise, or obliquely, each island may produce a separate pip. Surf breaking on a reef around an atoll often may produce a ragged, variable line of echoes.
11. Submerged objects do not produce radar echoes, but one or two rocks projecting above the surface of the water, or waves breaking over the reef, may show on the radar. When an object is entirely submerged and the sea is smooth over it, no indication will be seen on the scope.
12. If the land rises in a gradual, regular manner from the shoreline, no part of the terrain will produce an echo that is stronger than the echo from any other part. As a result, a general haze of signals will show on the scope, and it will be hard to determine the range to any particular part of the land. As a matter of fact, while the antenna is held still and the ship is not rolling, the apparent range to a shore of this sort may vary as much as 1000 yards. This variation may be caused by slight changes in propagation conditions that cause the beam to be moved up and down the slope.

As mentioned in item 1, land can be recognized by plotting the contact. You must be careful when doing this, because as your ship approaches or goes away from a shore behind which the land rises gradually, a plot of the ranges and bearings to the land may show an "apparent" course and speed. This may be explained by reference to figure 10-2. In figure 10-2 A, the ship is 50 miles from the land, but since the radar beam strikes at point 1, well up on the slope, the indicated range is 60 miles. At some later time, when the

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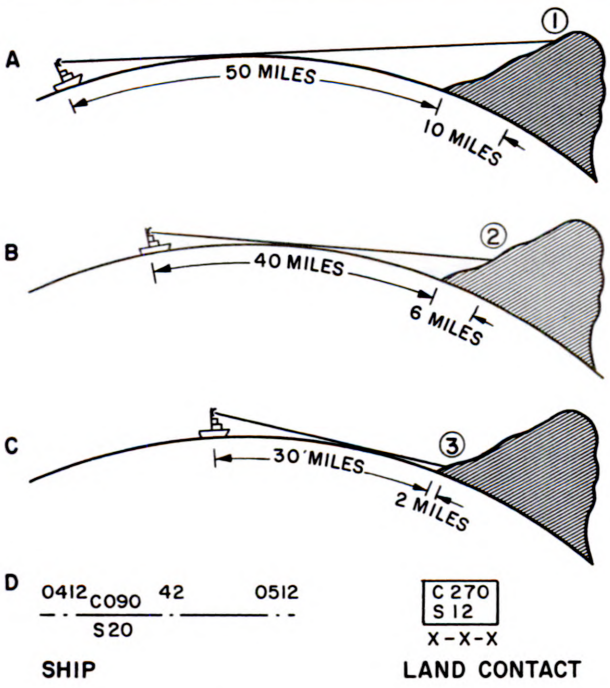

Figure 10-2.—Ship approaching land that rises back of shoreline.

ship has moved 10 miles closer to land, the indicated range is 46 miles because the radar echo is now returned from point 2. In figure 10-2 C, when the ship has moved another 10 miles, the radar beam strikes even lower on the slope, so that the indicated range may be 32 miles. If these ranges are plotted, the land will appear to be coming toward the ship at a speed of 12 knots, as shown in figure 10-2 D.

In the illustration, a smooth, gradual slope is assumed, so that a consistent plot is obtained. In practice, however, the slope of the ground will usually be irregular and the plot will be erratic, making it hard to assign a definite speed to the land contact. The steeper the slope of the land, the less will be its apparent speed. Furthermore, since the slope of the land does not always fall off in the direction from which the ship approaches, the apparent course of the contact need not always be the opposite of the course of the ship, as assumed in this simple illustration.

13. Blotchy signals are returned from hilly ground because the crest of each hill returns a good echo while the valley beyond is in a shadow. If high receiver gain is used, the pattern may become solid except for the very deep shadows.

14. Low islands generally produce small echoes. However, when thick palm trees or other foliage grow on the island, strong echoes are often produced because the horizontal surface of the water around the island forms a sort of corner reflector with the vertical surfaces of the trees. As a result, wooded islands will give good echoes and can be detected at a much greater range than barren islands.

A well-organized CIC should never have trouble recognizing land targets. When a target is picked up by the radar operator, the CIC supervisor should plot the target on a chart. If the target is land, it will be readily apparent.

SHIP TARGETS

The largest part of the radar operator's time on watch is spent searching out and tracking surface contacts.

You recognize a ship partly by a process of elimination. A small echo appears; checking your navigational position, the possibility of land in that sector is overruled. Also, the echo does not have the usual large, massive appearance that characterizes both land and cloud echoes. Aircraft are ruled out because the target appears relatively stationary. Finally, the appearance of the pip clinches it. A steel ship is an excellent reflecting body. The echo at a medium range is bright, clearly defined, and steady.

A good estimate can be made of the size and type of ship. One method is to work from the fact that large ships appear at greater ranges. Familiarity with the set will soon indicate the maximum expected range for detection of different types of ship targets. A target that first appears on a typical radar set at 20 miles is likely to be a destroyer or similar ship; something showing up at 10 miles is likely to be a surfaced submarine. Judgment of the nature of the ship can be helped considerably by knowing what is likely to be in the area.

Convoys are picked up at greater distances than single ships because of the larger reflection area provided by groups of ships. At a great distance the convoy will appear as a single large target, and may be mistaken for a small island. Here, again, the chart clarifies this mistaken identity. As the range closes on a convoy, individual ships can be distinguished. Within a range of 10 miles the number and formation of the convoy are determined by the number, position, and bearing of the echoes. The types of ships can be recognized by the appearance and

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strength of the echoes. The escorting ships are indicated by the movement of the small, bright echoes. The most important echo—in the case of friendly convoys—is that weak one lying alone a few miles outside the escort. That could be an enemy submarine against which the convoy is being guarded. Other characteristics of ship targets are:

1. Pip height bounces at a fairly slow rate on the A-scope. On the PPI the pip will brighten at times and then slowly decrease in brightness.
2. There are normally no fades except when range becomes too great.
3. Speed less than 50 knots.
4. Narrow, tent-shaped pip compares with land on the A-scope, though a large rock may give a similar pip at long range.
5. Small craft or fishing boats appear at about 4 or 5 miles and show extremely weak echoes. Plotting these contacts will show them to be moving at slow speeds.

PLANE TARGETS

The echo from an airplane appears much the same as an echo from a small ship. It shows a small, clear indication.

The easiest indication of an aircraft is the rapid motion of the echo on the radarscope.

Another indication of a plane is that its echo will fade and reappear again shortly. This is characteristic of any small, weak target but is more marked in the case of aircraft.

If height-finding equipment is available, a more definite check can be made by determining the altitude of the contact.

Since airplanes change aspect more rapidly than other types of targets, airplane echoes fluctuate more rapidly than those from other types of targets. The usual appearance of an airplane on the PPI-scope is that it will brighten and then rapidly decrease in brightness.

Helicopter and lighter-than-air craft targets are often mistaken for ships. The best recognition method is by observing the speed at which they move.

FALSE OR PHANTOM CONTACTS

On radarscopes many pips appear that look like echoes given off by planes or ships. It is important that you learn what causes these pips and how they look so that you can recognize them instantly.

Radar contacts made on targets that cannot be seen visually are often given the erroneous title of phantom contacts when actually they are caused by clouds, birds, fish, weather conditions, and wakes. All of these will reflect radar pulses to some extent. In general, echoes from these sources can be recognized by an alert operator.

SEA RETURN

Since some of the energy sent out by a radar strikes the surface of the sea, echoes are returned from the water when the surface is disturbed by waves.

Radar echoes from waves are called SEA RETURN. Sea return echoes show on a PPI-scope as an irregular bright area around the center of the scope. The range to which sea return extends on the indicator depends on the roughness of the ocean, the height of the antenna, and the peak power of the radar. In very calm water, there is almost no sea return. In rough weather, however, it is hard to see targets within several miles of your ship because all pips are lost in the clutter of echoes caused by sea return. Direction of wind will be shown in sea return because of the elongation of the area in the direction from which the wind is coming.

Figure 10-3 shows examples of sea return as seen on the A-scope and PPI. The effect of sea return on the indicator can be reduced, to a large degree, by lowering the receiver gain. Such an adjustment, however, prevents the radar from detecting objects at a distance. Radars are equipped with special circuits, as discussed in previous chapters, to reduce sea return to a large extent.

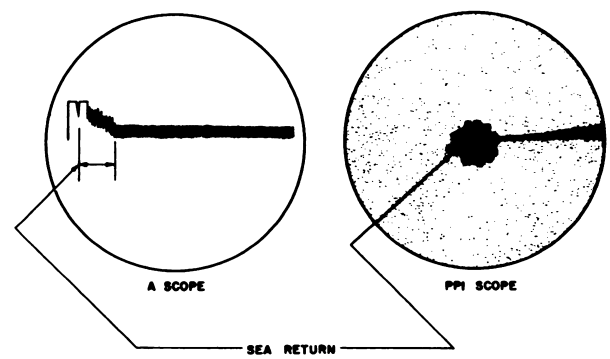

Figure 10-3.—Sea return.

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MINOR LOBES

The beam of waves sent out by your radar is not as perfectly shaped as the beam of a searchlight. Actually, if you could see the beam (viewed from above) as you can a beam of light, it would appear similiar to the one shown in figure 10-4.

The main, or major lobe, is in the direction in which the antenna is pointing, and a series of smaller lobes (not wanted, but unavoidable) point in various other directions. When these smaller lobes (called side lobes and back lobes) point at an object, they produce echoes, especially if the object is large and nearby. These minor lobes seldom extend out more than 6000 or 7000 yards. They will produce a picture on the PPI as illustrated in figure 10-5.

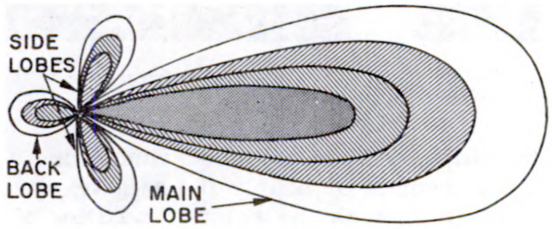

Figure 10-4.—Major (main) and minor (back and side) lobes.

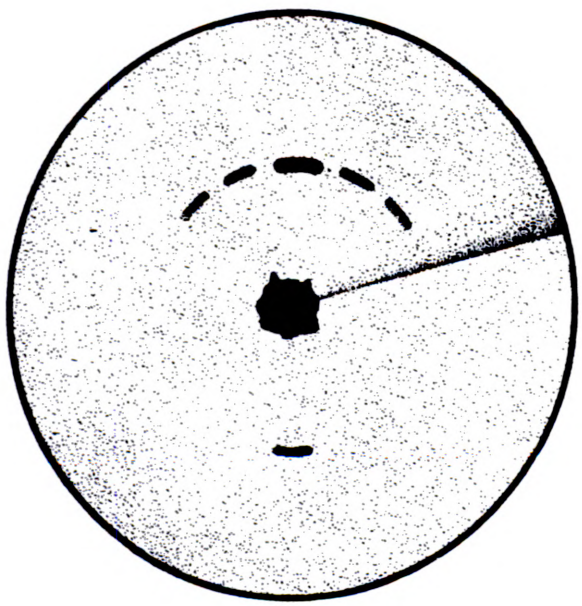

Figure 10-5.—Minor lobe echoes.

Notice that all the pips are at the same range. The largest pip is the real target; all others are minor lobe echoes. The minor lobe echoes can be made to disappear by turning down the receiver gain, but this procedure might also keep small targets from appearing on the scope. An alert operator would instantly recognize additional targets in this case because of the sudden appearance of bright echoes when they got into range of the minor lobes.

RADAR PULSES

Pips that move rapidly across the screen are often seen. There may be one or several. They are usually caused by another radar transmitter operating on or near the same frequency of your radar. We call them RUNNING RABBITS because of their unusual appearance on the scope.

DOUBLE RANGE ECHOES

Double range echoes are most frequently detected when there is a large target close aboard and on the beam. Such echoes are produced when the reflected beam is strong enough to make a second or third round trip, as shown in figure 10-6. Double range echoes are weaker than main echoes, and appear at twice the range. Triple range echoes are usually so weak that they are seldom seen at all.

Double range echoes can be very deceiving. If you do not recognize them instantly, you might make the mistake of reporting them as submarine periscope contacts. They can be useful also if used correctly. They can show if your radar is in calibration. The range from your ship to the target should be the same range as the range from the target to the second trip echo. One of the fleet exercises which will be conducted aboard your ship will consist of setting up an optimum condition with the purpose of obtaining these echoes for purposes of calibrating the radar.

SECOND SWEEP ECHOES

Second sweep echoes may occasionally be seen on the scope returned from land targets beyond 125 miles on a radar using a PRR of 650 pulses per second. For example, a mountain at 135 miles would give a target on the PPI at an apparent range of 10 miles, which is the difference between the actual range (135 miles) and

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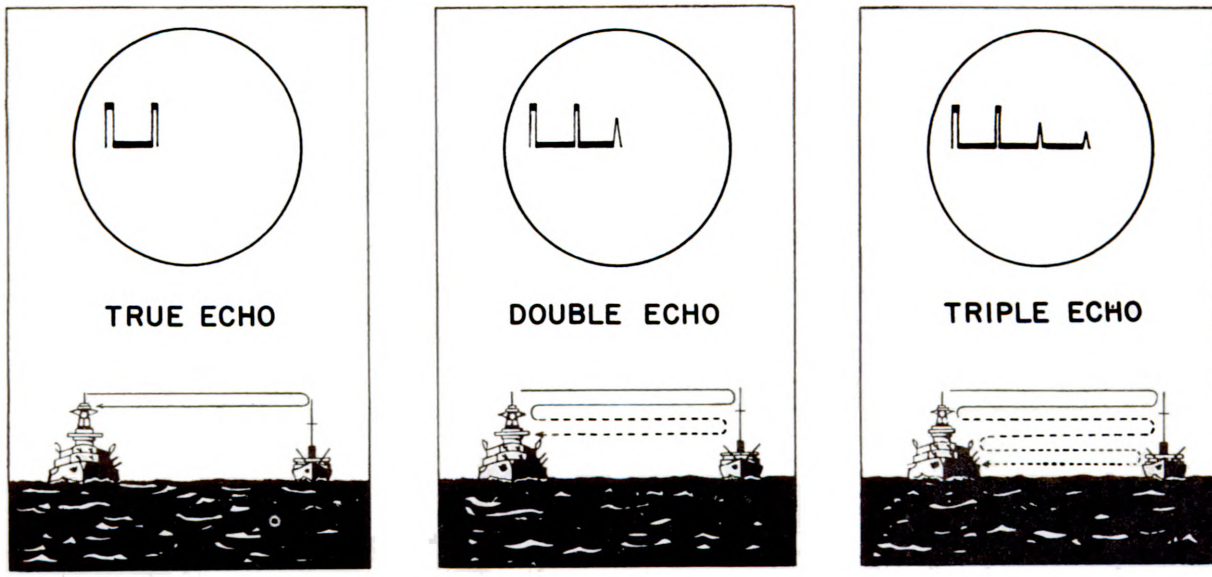

Figure 10-6.—Multiple range echoes.

the period between pulses (125 miles). However, when the PRR control located on the radar set control is changed, the apparent range of the second sweep echo will slowly increase or decrease along the same radius on the indicator. As the pulse repetition rate is increased, the time between pulses decreases and the sweeps start more often per second, so that the apparent range of the second sweep echo will increase; that is, the target will appear to move outward on the scope. As the PRR is decreased, the target will appear to move inward. Second sweep echoes can therefore be recognized by varying the pulse repetition rate and noting whether the target moves across the PPI.

REFLECTION ECHOES

Reflection echoes are sometimes seen due to the reflection of the radar beam from some surface aboard your own ship. It results in a contact at the correct range, but at the wrong bearing. To prevent reporting false bearings, you should know the relative bearings on the radar where you might expect trouble from reflection echoes.

WAKES

The wakes from two ships that are steaming close together, on parallel courses, will intersect at a point on the quarter of both ships. The intersection travels at roughly the same speed as the ships, and can produce a fluctuating echo that will remain at nearly the same range and bearing as long as the relative position of the ships is unchanged.

Occasionally the radar will pick up the wake produced by a large ship that is nearby, especially during turns of the target ship or when it is running at high speed. Pips from wakes are small, have poor definition on the PPI, and are near to and astern of the echo of the ship causing them.

STORMS AND CLOUDS

Sometimes your radar may act as a weather prophet by indicating rain squalls, clouds, and regions of sharp temperature differences.

Microwave radars are particularly effective in detecting cloud or storm echoes.

Knowledge of the actual reasons why radar pulses are returned from storm clouds is still incomplete, but it is generally believed that the reflection is due to scattering caused by water droplets. The amount of scattering increases very rapidly with the radar frequency, so that storm echoes are most often seen on S- and X-band radars. Cloud echoes are rare at frequencies below 1000 megacycles. Experience has shown that clouds do not produce visible echoes unless the water drops within the cloud are large enough to yield rain. This does not mean that there is rain at the ground level when storm echoes are observed. This is because the drops

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may evaporate before they reach the ground, or because rising currents of air may keep the drops in the air thus defying gravity. This latter phenomenon is very common in cumulus type clouds and thunderheads.

As a result, not all clouds can be seen on a radarscope. Stratus clouds give very little echo or perhaps none at all. Therefore, a general overcast is often invisible to the radar operator. Thunderstorms and frontal squalls, however, usually produce bright pips on the scope. Thundershowers are of two general types. The isolated air mass or convection storm produces a bright, dense echo surrounded by haze, like the echoes shown in the southern sector of figure 10-7, A. The other type of thundershower may occur with a cold front. These are commonly known as line squalls. The echo from such a cloud formation may show as a bright line if the storm is fully developed, or it may show as a group of bright spots caused by echoes from individual showers along the front, as illustrated in figure 10-7, B.

Unless trained to recognize these types of echoes, operators may interpret them as valid targets. If, however, such echoes are readily evaluated, it may be possible to vector aircraft around the storm areas and to maneuver carriers into clear areas where planes may be more easily launched or landed.

Usually, storm echoes are not so strong that they blank out the much sharper contours of a plane echo. If the echo from the storm should be strong enough to hide the plane echo, the air in this area would be so rough that it is not likely that a plane would intentionally fly in this part of the atmosphere. Therefore, enemy planes will not normally seek cover in such storms.

Since radar can detect objects on each side of the storm area, little protection from radar detection is given airplanes by violent localized storms. The operator can usually recognize cloud echoes by their fuzzy, misty, cloudy appearance on a PPI. If the pip is too sharply defined to allow ready recognition of the echo as a cloud contact, a comparison of the target course and speed against known wind data, along with position angle provided by the height finder, will permit the echo to be properly evaluated.

Since clouds often extend over several miles and may rise to heights of 40,000 feet, they produce echoes at extremely long ranges. Furthermore, the echoes may cover large areas on the indicator. In some unusual instances, the entire PPI-scope may be so covered with cloud echoes that it is impossible to see other targets.

A. AIR MASS OR CONVECTION THUNDERSTORM

B. THUNDERSHOWERS ALONG A COLD FRONT

Figure 10-7.—Thunderstorm echoes on PPI.

Because cloud echoes, like sea return, are longer than the echoes from more solid targets, both IAVC and FTC are of considerable use in reducing interference from clouds. For example, figure 10-8, view A, shows a large area of the PPI-scope blotted out with cloud echoes. The clouds that cover the center of the screen are quite dense, but those at 3 o'clock and at 9

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o'clock show a more hazy appearance. In figure 10-8, view B, the same clouds are shown, except that the radar is transmitting a 1/4-microsecond pulse instead of a 1-microsecond pulse. The increased resolution produced by this change reduces the density of the cloud echoes, but they are still troublesome. In figure 10-8, C, the transmitted pulse duration is again 1 microsecond, but the IAVC circuit is switched on. Here the cloud echoes are considerably reduced. With both IAVC and FTC turned on, the cloud echoes are reduced to almost negligible proportions (fig. 10-8, D). Another thing an operator can do in trying to detect contacts in storms is to use the gain control to reduce the cloud interference. This is not normally desirable because of the reduction in size of smaller close-in targets.

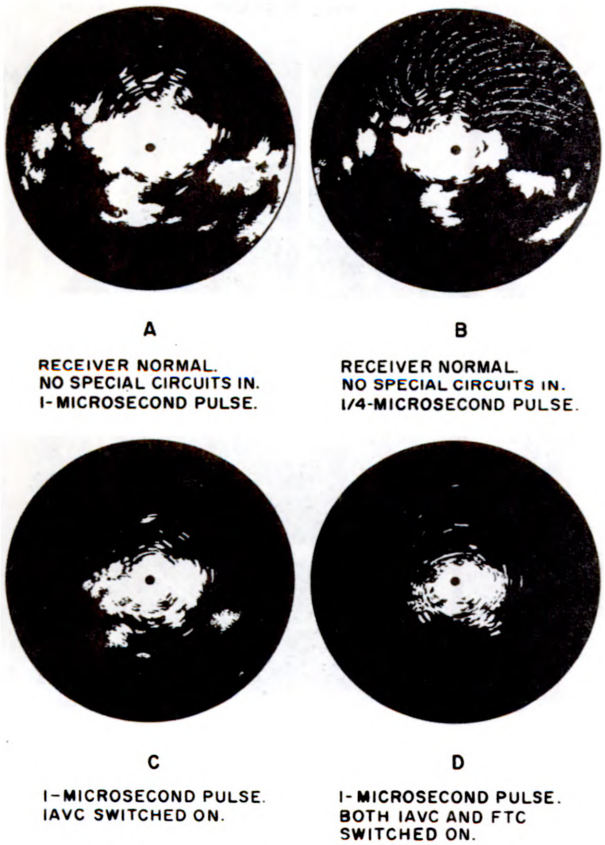

Figure 10-8.—Cloud echoes on PPI.

MISCELLANEOUS FALSE CONTACTS

At close range you may get some other false echoes that seem unaccountable. They may be from whitecaps (beyond sea return in the direction from which the wind is coming), from birds, or from floating objects such as large tin cans, powder cases, or even seaweed.

The echoes from flying fish or birds are faint and fluctuate rapidly as a rule. In addition, the behavior of birds is usually so different from any other type of airborne target that continued observation of the movement of the echo should reveal it as a bird. Since birds and fish are relatively small, they can return echoes only at short ranges. A visual check by lookouts or other topside personnel will help the operator in determining the cause of these targets.

ATMOSPHERIC NOISE

The frequencies used for radar are so high that atmospheric noise, or static, has little effect on its operation. The noise which normally shows on an indicator is produced in the early stages of the receiver. Other strong pulses, similar to noise pulses, have been observed on some radar indicators as a result of nearby lightning flashes. On occasion, 200-megacycle radar has encountered serious interference from St. Elmo's Fire. The aurora borealis, which interferes so greatly with most communications, seems to have no effect on radar.

ROLL AND PITCH OF SHIP

Occasionally a radar operator has a difficult time getting a target to remain on his scope long enough to interpret properly. This is due to the roll and pitch of the ship in heavy seas. The state of the weather had relatively little effect on earlier models of low-frequency radars, but the more recently developed equipment operates on very short wavelengths, and may be greatly affected by weather. When the vertical width of the beam is narrow, the rolling of a ship may cause the radar to miss targets on some sweeps. In small ships the amount of roll is often great enough to prevent the reliable use of radar. Stabilized antennas are necessary in radars used to determine altitude of airborne targets by measuring position angle (such as the AN/SPS-8). With air search radars, the vertical beam width is usually no narrower than 20°. Here, the roll of the ship is usually insufficient to pull the beam off target. Thus, a good procedure to follow when attempting to track a surface contact that is fading off the scope occasionally, is either to get the range and bearing when possible, make use of a stabilized height finder, or to shift the tracking duties to the air-search radar operator.

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PPI INTERPRETATION

RADAR SHADOWS

To visualize land as radar sees it, imagine yourself looking down from a point high in the sky at about sunset. The light from the setting sun will illuminate the parts of land that a radar on the same bearing would SEE, but there will be shadows behind the mountains. These areas will be RADAR SHADOWS and therefore not detected by the radar. Figure 10-9 is another illustration of radar shadow.

BEAM WIDTH DISTORTION AND PULSE LENGTH DISTORTION

So much for the points of similarity—now analyze the differences. Two types of distortion are always evident in PPI presentations. One is due to the spreading beam of the radar and can be called beam width distortion; the other is caused by the pulse not being instantaneous and this is called pulse length distortion.

Beam width distortion results in the widening of everything detected by radar. That is, all contacts appear to spread to the left and right of true position. This will be noticed more on air search radars with a wide beam than it will on surface search radars. The stronger the echo, the greater the spread.

Pulse length distortion results in increased depth of target pips on the range axis of the scope. For example, a small navigation buoy may give a pip 300 yards deep on the A-scope.

As you have probably noticed on the PPI, contacts spread more in bearing than in range.

On the PPI, a straight shoreline often looks crescent-shaped. The effect can be seen on any radar occasionally, but is most pronounced on air search gear. The crescent shape effect is caused by beam width distortion. The wider the beam width, the greater the distortion.

The coastline distortion is negligible at points where the shore is at right angles to your antenna, but as the angle decreases the shoreline distortion increases.

SIDE LOBE RINGING

At times, the crescent-shaped effect is so pronounced that, according to the PPI, you seem to be in a land-locked harbor or lagoon, when actually you are off a straight, mountainous

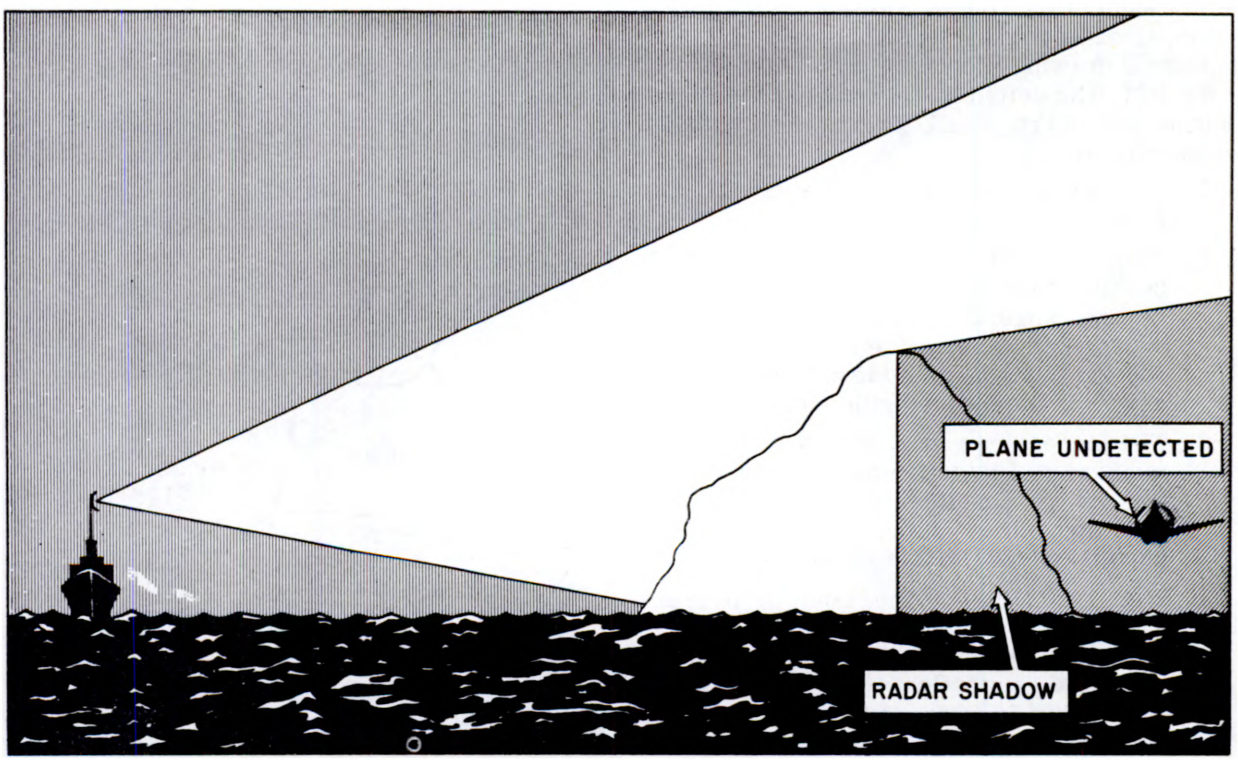

Figure 10-9.—Radar shadows.

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shoreline. This complete ringing effect appears on air search radar and is very confusing to aircraft control officers and others concerned with control of aircraft. Side lobe ringing is due to a combination of both beam width distortion and side and back lobes.

LOW LAND

Radar frequently fails to detect low-lying, and gradually sloping land, especially at long range. This results in another distortion of coastline.

SHIPS NEAR SHORE

Ships or rocks close to shore may blend with the shoreline, and either lose their identity altogether when picked up on the same line of bearing. This effect is caused by the spreading effect of all targets, both in range and bearing.

ANALYZING A PPI PATTERN

The two drawings in figure 10-10 summarize the various distortions we have been discussing. The first shows the actual shape of the shoreline and the land behind it. Notice the radio tower on the low sand beach, the two ships at anchor close to shore, and the lighthouse. The heavy line in the second drawing shows how the land will look on the PPI. The dotted lines represent the actual position and shape of all targets. Notice these things in particular:

1. The low sand beach is not detected by the radar.
2. The tower on the low beach is detected, but it looks like a ship in a cove. At closer range the land would be detected and the cove shaped area would begin to fill in; then the radio tower could not be seen without reducing the receiver gain.
3. The increasing radar shadow behind both mountains. Distortion due to radar shadows is responsible for more confusion than any other factor. The small island does not show for this reason.
4. The spreading of the land in bearing caused by beam width distortion. Look at the upper shore of the peninsula. The shoreline distortion is greater to the west. This is because the angle between the radar beam and the shore is smaller as the beam seeks out the more WESTERLY SHORE.
5. Ship No. 1 looks like a small peninsula. Her contact has merged with the land because of the beam width distortion. If the land had been a much better target than the ship, the ship would have been completely wiped out.

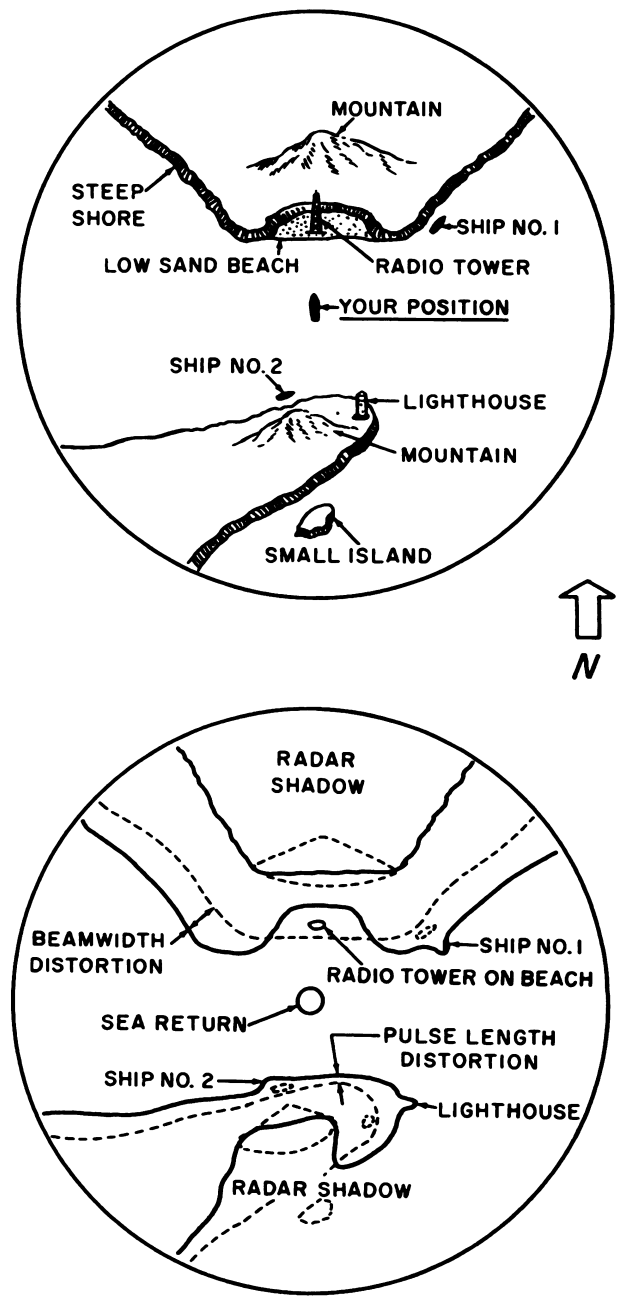

Figure 10-10.—The effect of beam width and pulse length distortion.

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6. Ship No. 2 also merges with the shoreline and forms a bump. In this case, it was caused by pulse length distortion. Reducing receiver gain might cause the ship to separate from the land, provided she is not too close to the shore.
7. The lighthouse also looks like a peninsula, because of beam width distortion.

OTHER TRICKS OF THE TRADE

COURSE CHANGES

In many cases you can tell when a target changes course before the fact is revealed by the plot. The change can be indicated by an increase (or decrease) in signal strength of the echo because of increased (or decreased) presentation. Small changes in course will not cause any noticeable signal difference. Therefore, any change you can see will be important even though you do not know which way it is turning. Report possible course changes immediately.

BLIND SECTORS

You know now that radar shadows exist behind objects that reflect radar energy. If the antenna for your radar is not mounted higher than everything else, a blind sector may exist. Such things as masts, superstructures, and other antennas can cause radar blind sectors. Most ships have prepared charts showing the blind sectors. Know the blind sectors on the radar you are operating.

SUMMARY

You can see that there is more to learning to be an efficient radar operator than just studying the information in a book. It is going to take a lot of experience that can only come from actual radar operation. On the other hand, operating time alone means nothing unless you get in the habit of observing and analyzing every signal that appears on the scope—then checking your estimation against visual reports.

QUIZ

1. Define echo interpretation and composition.
2. Name four characteristics of pips which give information useful in interpretation.
3. What is the only positive thing the size of a pip will tell you?
4. When is target angle an important consideration in determining the size of a target? What is the definition of target angle?
5. How can fluctuation and rate of movement help in determining the size of a target?
6. Briefly, what is a one pip area?
7. How can the number of aircraft in a formation be estimated?
8. Why does a land target appear to move on the PPI-scope?
9. How does target speed help you to differentiate between air and surface targets?
10. What is meant by false echoes? Name three types.
11. Define the term "radar shadow." What is the result of beam width distortion? Pulse length distortion?
12. What three factors combine to produce side lobe ringing?
13. What might a sudden increase in target signal strength denote?
14. What is the cause of blind sectors?

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CHAPTER 11

MAINTENANCE AND SAFETY

PREVENTIVE MAINTENANCE

In some respects, shipboard electronic equipment and the family automobile have a lot in common. They will operate at peak efficiency only if they are cared for properly. For a car this usually means various checkups and adjustments that should be made after it has been operated for a certain number of miles.

To carry the analogy a little further, a lot of people take understandable pride in being able to make a great many of these tests and adjustments themselves. Being able to perform most of the routine work, they acquire an increased understanding of how the car works. Ordinarily they can make the repairs in much less time than a mechanic at a busy garage, and often they can save money. If they are consistent and thorough with these checkups, they will prevent a lot of trouble before it really starts.

The same principles of PREVENTIVE MAINTENANCE apply to electronic equipment. No matter how skilled the operators may be, the ability of the CIC team to perform efficiently depends entirely on the performance of the equipment.

The Navy believes that equipment operators can do a great deal toward keeping performance high by routine servicing, by checking, and by making minor repairs.

Operators gain a knowledge of equipment that otherwise would be impossible by performing such tasks as cleaning the inside and outside of the equipment; inspecting for binding of controls, loose knobs, burned-out pilot lights, and missing spare fuses; measuring ring-time range; checking the operation of scope range scales, antenna rotation, bearing alignment accuracy, and waveguide condition; tuning the equipment; and taking meter readings. A realistic and systematic program of preventive maintenance will also keep the equipment operating longer and more efficiently, save precious time and money by preventing many costly failures, and release technicians for more complex repair jobs.

This chapter deals with some of the more common procedures pertaining to operators' preventive maintenance. In addition to telling you how to perform these jobs, considerable emphasis will be placed on the safety precautions that must be observed when working on electrical or electronic equipment.

TEAMWORK

The two general categories of ratings responsible for proper performance of electronic equipment are operators and technicians. At times, the duties of these men are so closely related that they must work together as a team. As we know only too well in the Navy, "It takes teamwork to get the job done." Thus, an operator and a technician are often teamed together and share responsibilities for preventive maintenance and proper mechanical and electronic repairs as the need arises.

The maximum degree of reliability of a radar would be obtained if one man were assigned the duty of operating, repairing, and maintaining one particular radar. This would require extensive training on the part of the Navy and also extensive reorientation of Navy training methods. Such a reorientation is not practical under current personnel limitations. Consequently, in today's Navy we have a technician with broad electronic training taking care of large numbers of equipments. Few in number, they are responsible for corrective maintenance, troubleshooting, and repairing electronic equipment whenever the repair is too big or too complex for the operator.

OPERATORS' RESPONSIBILITIES

Inasmuch as Radarmen spend a good part of their training time learning to operate equipment under fleet conditions, their troubleshooting knowledge and repair experience are necessarily limited. As a result, an operator's

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responsibilities concerning electronic equipment are less complex than the ET's, but just as important. The radar operator's responsibilities come under the heading of operational use, manipulation, operational maintenance, and preventive maintenance.

Operational Use

Operational use is defined as utilizing electronic equipment to the extent of its capabilities, and applying advantageously the information obtained.

Manipulation

Manipulation is the manual process involved in starting, stopping, and adjusting external controls so as to realize best performance from the equipment.

Operational Maintenance

Operational maintenance normally consists of inspection, cleaning, servicing, preservation, lubrication, and adjustment as required. It also may include replacement of minor parts not requiring high technical skill or internal alignment.

Preventive Maintenance

Preventive maintenance is the systematic care, usually on a scheduled basis (daily, weekly, monthly, etc.), considered necessary to reduce or eliminate failure of the equipment. Items comprising preventive maintenance are more specifically defined and outlined in the technical manuals and POMSEE books furnished with each equipment.

TECHNICIANS' RESPONSIBILITIES

Technicians' responsibilities toward a piece of electronic equipment include manipulation, repair, corrective maintenance (ordinarily limited to maintenance consisting of replacement of unserviceable parts, subassemblies, or assemblies, and the alignment, testing, and internal adjustment of equipment), and preventive maintenance which requires realignment after accomplishment.

SAFETY PRECAUTIONS

Before you start cleaning or servicing any electronic equipment, certain precautions must be taken to protect yourself as well as the equipment.

As a petty officer, you will be charged with the safety and well-being of all nonrated men on the radar preventive maintenance force under your direction. At the same time, you will be directly responsible to the CIC officer for the proper functioning of the radar systems.

Attitudes of men toward safety are important. In their concern for optimum functioning of gear, many Radarmen neglect the safety warnings in instruction books that accompany every piece of equipment. To impress all hands that their first duty is to keep themselves, as well as their equipment, in fighting trim is an important responsibility of the CIC officer, and you will share in this responsibility.

Although every radar has its own safety precautions, several major precautions that apply generally will be discussed here.

You are urged to read at the first opportunity all the bulletins and publications concerning safety precautions. A few of them are: Safety and First Aid in the BuShips *Electronics Installation Practices Manual; Electric Shock and Its Prevention,* NavShips 250-660-45; chapter 18 of OpNav 34P1, *U. S. Navy Safety Precautions; Standard First Aid Training Course. NavPers* 10081; and chapter 67 of *BuShips Technical Manual.*

HIGH VOLTAGE

As a Radarman's ability with equipment increases, there often develops an increasing disregard for the dangers inherent in high voltages. This is unfortunate, because these voltages can be LETHAL, and there is no physical sense that reliably warns of their presence. For these reasons, high-voltage warning signs are prominently posted on and near electronic equipment, and must be obeyed. Before performing any maintenance or cleaning operations on electronic equipment, always make sure that voltages are not present.

WORK PERFORMED BY AUTHORIZED PERSONS ONLY

Because of the danger of fire, damage to expensive material, and injury to personnel, all repair, maintenance, and cleaning inside electronic equipment should be performed only by duly authorized and assigned persons.

Knowing your equipment well is the most effective tool for assuring your safety when cleaning and servicing the equipment. You should be completely checked out by a qualified person

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before attempting any cleaning or preventive maintenance duties yourself. Also study the instruction book and familiarize yourself with the operation of the equipment. Pay particular attention to important items such as safety interlock circuits. The purpose of these circuits is to prevent accidental operation of the equipment with the doors open. Do not, however, depend on interlocks to remove power when doors are opened. It is possible to disable the protective circuits, when necessary, thereby making the operating component accessible for testing and checking.

TAGGING OPEN SWITCHES

The best method of assuring that there is no voltage inside a cabinet is to turn off the main power source. Some equipments have heater circuits and synchro voltages which are on a line other than the main power source, so you should be sure that they also are secured.

After securing the main power switches or cutout switches in each circuit from which power could possibly be fed, each switch must be tagged. A tag serves as a warning so that no one will turn the power back on while you are working on the gear. The tag should read: "This circuit was ordered open for repairs and shall not be closed except by direct order of_____" (usually the person making, or directly in charge of, the cleaning or repairs). When the work is completed, the tag is removed by the same person.

SHORTING/GROUNDING BAR

Even when secured, electrical and electronic equipment may retain a charge sufficient to cause a severe shock. BE SAFE! Discharge and ground the circuit components before you work on them.

The shorting/grounding bar shown in figure 11-1 affords a safe way to ground deenergized circuits. Connect the flexible lead to a grounded part of the cabinet or chassis by means of the alligator clip. Always make this ground connection first. Then, holding only the insulated handle, touch the copper probe to the circuit or part you want to discharge to ground.

Prior to touching a capacitor which is connected to a circuit, short circuit the terminals with the shorting bar. This should be done even though you know the power has been turned off or disconnected entirely.

Some electron tubes that have caps with a connecting wire on top are about as dangerous as capacitors and must be treated with caution. Before touching this type of tube, always short it as you would a capacitor.

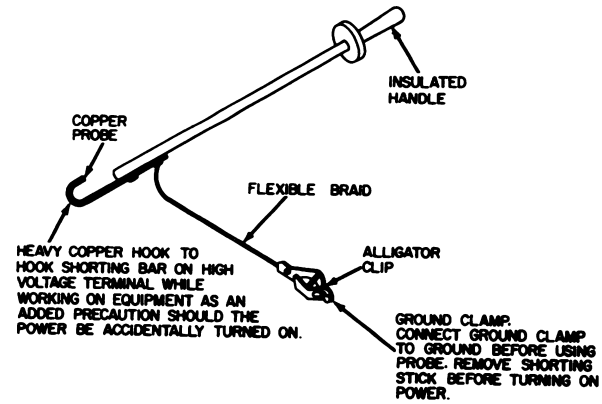
INSULATED HANDLE
COPPER PROBE
FLEXIBLE BRAID
HEAVY COPPER HOOK TO HOOK SHORTING BAR ON HIGH VOLTAGE TERMINAL WHILE WORKING ON EQUIPMENT AS AN ADDED PRECAUTION SHOULD THE POWER BE ACCIDENTALLY TURNED ON.
ALLIGATOR CLIP
GROUND CLAMP. CONNECT GROUND CLAMP TO GROUND BEFORE USING PROBE. REMOVE SHORTING STICK BEFORE TURNING ON POWER.

Figure 11-1.—Shorting/grounding bar.

So far we have discussed a few safety precautions that must be observed prior to cleaning or servicing electronic equipment. It is necessary now to stress some additional safety precautions to comply with when working with electronic equipment.

1. Check the installed safety devices prior to working inside an electronic equipment when power is on.
2. Whenever possible, avoid working inside electronic equipment when the electricity is turned on. If it becomes necessary, make certain an assistant qualified in resuscitation and other first-aid techniques is at hand.
3. Stand on a rubber mat and use rubber gloves where practicable.
4. Never climb the mast without permission of the OOD. Personally check to ensure that dangerous circuits are deenergized before going aloft.
5. Because cathode ray tubes might implode if dropped or bumped, a face protector and gloves should be worn by personnel handling the tubes. Cathode ray tubes should not be carried by the neck of the tube, that being the weakest part.

CLEANING AND INSPECTING ELECTRONIC EQUIPMENT

Since Radarmen are responsible for cleaning and inspecting electronic equipment, it is necessary that you learn safe cleaning procedures and what to look for while cleaning. First, though, let us briefly review the basic requirements of

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an electrical circuit so that you will better understand the discussion on circuit faults.

ELECTRICAL CIRCUITS

For electrons to move, the first requirement is a source of electromotive force (emf). The emf may be supplied by any source of electricity—friction, pressure, heat, light, magnetism, or chemical action.

Next requirement is that the circuit contain one or more components that make use of the motions of the electrons. Such a component is called a load.

The third requirement is that a circuit must contain connecting wires to conduct the electrons from the source of emf through the load and back to the source of emf. These wires must be connected in such a way that the electrons flow in a closed loop.

CIRCUIT FAULTS

It would be almost impossible to list all radar equipment casualties. However, most of them are classified as either mechanical or electrical.

The majority of these casualties can be prevented by the Radarman through careful observation while cleaning the equipment.

A good visual inspection of the equipment will reveal signs of possible trouble. Look for excess oil resulting from overlubrication, a frayed wire that could be a potential short, a loose switch, or a loose tube clamp. Let us see how these will cause circuit faults.

Circuit faults are classified as OPENS, GROUNDS, and SHORTS. The end result of these faults is to decrease or cut off the current, or to increase the current beyond a safe value. Sometimes—not often—circuit faults are unavoidable. Make sure they are unavoidable when you are assigned the duty of maintaining a piece of equipment.

Short Circuit

A short circuit is a fault which occurs in electrical circuits when some part of the connecting wires touch each other in such a way that the electrons do not flow through the load but through a shorter path from one side of the source of emf directly to the other side. Since there is no load to supply "resistance" to the electrons, the electron flow becomes so large that much heat is generated in the connecting wires and source of emf, and either or both may be destroyed. When inspecting the equipment for short circuits, you should be particularly careful to detect frayed wires with worn insulation. This is the most common sign pointing to the existence of a short. Several things can cause insulation to wear through. Most often this condition is due to (1) melting caused by heat generated when the equipment is operating, (2) breakdown resulting from salt water corrosion, or (3) friction from vibration of the equipment.

Figure 11-2 illustrates one way in which a short circuit can occur and what happens when it does. In this example, the insulation has broken in the cable going from the power supply to the modulator. Because of this breakdown the two conductors are touching each other and the current now travels from the source (power supply) to the short (point of contact) and back to the source. The short has provided an easier path of low resistance.

The current is extremely high because the short offers practically no resistance to it. This current may be high enough to heat the wires to a red-heat, melting the insulation and—if not detected in time—eventually burning out the power supply.

To prevent this eventuality, a fuse is inserted in the line, usually close to the source of energy. A fuse, as you know, is a safety device for opening a circuit when current flow exceeds a safe value. Each fuse contains a soft metal that will melt and open the circuit when heated by excessive current. As an aid to speedy replacement, most equipments have fuse indicator lights that glow when the fuse burns out. These indicator lights are shown in figure 11-2.

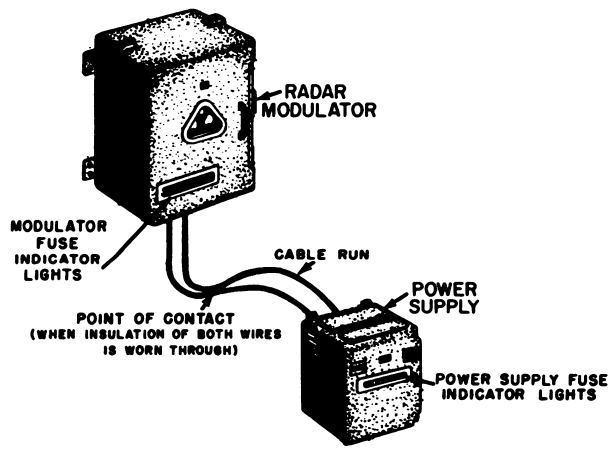
RADAR MODULATOR
MODULATOR FUSE INDICATOR LIGHTS
CABLE RUN
POWER SUPPLY
POINT OF CONTACT (WHEN INSULATION OF BOTH WIRES IS WORN THROUGH)
POWER SUPPLY FUSE INDICATOR LIGHTS

Figure 11-2.—Short circuit.

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All radar component circuitry is protected by fuses. They are rated at different amperages and voltages. Rating is extremely important and is marked on the fuse itself. Special care must be taken when replacing fuses to make sure that a blown fuse is replaced with one of exactly equal rating. If this is not done, severe damage to the equipment may occur. Many radar equipments have holders of spare fuses located next to the fuse clips in use. One of your duties will be to keep these spare holders filled.

When removing and replacing the fuses that are held in clips, always use insulated fuse pullers (located adjacent to the spare fuses). If, after replacing a fuse, it burns out again, you should notify the technician to investigate the cause.

An inexcusable cause of short circuiting is carelessness in closing equipment cabinets after cleaning or servicing the inside of the equipment. Most equipments are made as compact as possible, and if a loose wire falls in the way along the track the equipment slides on, the loose wire may be clipped. When power is applied and the ends of the two wires touch a metal object, the electrons follow the path of least resistance, and a short results.

Open Circuit

Another type of fault you should know about is the open circuit. This does not cause the damage that a short does, however. It has a completely opposite effect—nothing happens. An open circuit is one in which there is an incomplete circuit for the electrons to flow through. A break or poor connection may occur in the connecting wires, in the load, or in the source of emf so that the electrons cannot jump across the resulting open circuit.

As a general rule, most open circuits in a radar are caused by blown fuses and faulty interlocks. An open circuit could, of course, result from dirty or loose connections.

Good connections are CLEAN and TIGHT. If a connection is perfectly clean, makes good contact over a large area, and is tight, NO RESISTANCE IS ADDED to the circuit. But, if a connection is dirty, or has small contact area, or is loose, considerable resistance is introduced in the circuit.

Dirt, oil, corrosion, or dust between connection points will keep the contact's surfaces from touching and may stop or almost stop the flow of electrons. If any such obstruction prevents the two parts from touching, only a small amount of current may pass. Consequently, the equipment may not work at all; or, if it does, it will not perform at peak efficiency. In addition to interfering with the operation of switch and relay contacts or terminals, dirt and grime may cause overheating. If dust and corrosion remain on an insulator, arcing over or even grounding of the circuit may result.

Dirt and grime on a resistor may create an overheated condition of the resistor, changing its value. This, in turn, may cause circuit adjustments to be unattainable, or may cause incorrect performance of the circuit.

Casualties to resistors are mainly of two types: those brought about by a change in value, and those caused when the resistor burns out. Both conditions may be due to failure of an associated part or to maladjustment of the circuits from overheating. An open or shorted resistor may result in the equipment being inoperative.

Grounds

Grounds and shorts are closely related in that two grounds, one on each side of a line, cause a short circuit. Even partial grounds can give trouble by creating excessive current in the wires. To detect grounds before they become serious, daily ground tests with a megger are taken on some pieces of equipment by the technicians. The megger, as you learned from studying *Basic Electricity*, is a special ohmmeter for measuring insulation resistance. Some circuits have an intentional ground at the chassis of the equipment.

CLEANING INSIDE THE CABINET

To clean a radar properly, remember that—

1. Dust and dirt must be removed carefully to avoid dislodging tubes, causing misalignment of components, thus more damage.
2. To be safe, the proper cleaning tool must be used.

A vacuum cleaner with a nonmetallic hose, though safe and useful, will not reach all areas where dust accumulates. The preferred method for cleaning the chassis and cabinets of equipment is to use a soft brush having no metallic parts to loosen dust for easier removal by the vacuum cleaner.

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CLEANING AND INSPECTING CONTACTS

The most common method of cleaning contacts and relays is to use a vacuum cleaner or a clean, dry cloth. The contact surfaces should be inspected as the cleaning is done. If contacts are dirty and pitted, the technician in charge of the equipment should be notified. He will either replace the contact or use a burnishing tool to polish the contact. Under no circumstances is sandpaper, emery cloth, or a coarse file to be used. Such materials may result in malfunctioning of the relay. Careful burnishing, when needed, prevents excessive pitting or corrosion of contacts.

Loose connections may occur at the knives of switches, spring clips, and bolt terminals. While cleaning, loose connections at bolt terminals should be checked and should be tightened.

After electronic equipment has been in operation for some time, vibrations may produce loose connections, especially after firing guns or because of stormy weather conditions. Loose connections sometimes cause sparks, and the current drops below its rated value. Because of their arcing, loose connections are fire hazards and may burn insulation and possibly do considerable damage.

CLEANING AND INSPECTING CAPACITORS, INDUCTORS, AND TRANSFORMERS

Inspect all terminals of capacitors, inductors, and transformers for corrosion and loose connections, and check for indications of oil leakage. If any oil or tar is found, report it to the technician. He should replace the part, if necessary. Clean cases and ceramic insulating bushings with a clean, dry cloth.

If tar and oil caused by a leaky transformer or oil-filled capacitor cannot be removed with a soft, clean, dry cloth, a solvent must be used, but only if absolutely necessary. Some solvents are flammable, others are toxic (poisonous), and still others are both flammable and toxic. Besides these hazards, all solvents are harmful to electronic equipment. They dissolve waxes and compounds that protect equipment from fungus growth. Also, they soften most types of insulation and cause it to become saturated with the very dirt, tar, or oil being removed. The commonly available chlorinated solvents combine chemically with wax and oil to produce enough hydrochloric acid to etch metal surfaces, causing such troubles as erratic operation of switch contacts. Therefore, solvents should never be employed for general cleaning of electronic equipment. In other words, use solvents to clean only those parts that the vacuum cleaner, brush, or cleaning cloth will not remove. To apply a solvent, wet part of a soft cloth and then wipe off the tar or oil, making sure no other parts are touched with the solvent.

Flammable solvents such as alcohol must never be used on energized equipments or near any energized equipment from which a spark may be received.

Be sure the area is well ventilated when working with toxic solvents, and use only the smallest possible quantity of solvent necessary to do the job.

Carbon tetrachloride no longer is authorized by the Navy as a cleaning agent. Many serious accidents were caused by the improper storage and use of carbon tetrachloride, resulting in headaches, dizziness, nausea, loss of consciousness, and even death. Actually, it is more poisonous than carbon monoxide. A new solvent, methyl chloride, has been approved for cleaning applications for which carbon tetrachloride previously was used. Even though it is less toxic than carbon tetrachloride, the new solvent does present some hazards to personnel, and the following safety precautions must be observed:

1. Use with adequate ventilation.
2. Avoid prolonged or repeated breathing of the vapor.
3. Avoid prolonged or repeated contact with the skin.
4. Do not take internally.

CLEANING AIR FILTERS

You may believe that if equipment is clean on the outside, it likewise must be clean on the inside. This is not always true, however. But it is true that if the equipment is kept clean on the outside, and the space surrounding the gear is clean, there is less chance of dust and dirt entering the inside.

Most modern electronic equipment is made practically airtight. Nearly all such equipment contains electron tubes, transformers, and the like, that produce considerable heat, making cooling systems necessary. Such a system usually consists of a blower motor that pulls in cool air through a filter. If dust and dirt accumulate on the outside and around the equipment, the filter will clog, forcing the blower to work harder. This causes the blower itself to produce heat. For this reason, filters must be

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checked periodically and cleaned when the need arises.

Air filters are used in most cases in the radar modulator, receiver-transmitter, repeaters, and power supplies. To inspect filters, open the filter door (case) by loosening the wing nuts. If the filter is dirty, remove it. Most of the time the vacuum cleaner will clean filters satisfactorily. If the filter is particularly dirty, you must wash out accumulated dust by hosing the filter with hot water or by allowing water to float through the filter from the clean side. Then wash the filter in a solution of hot water and washing compound; rinse, and allow to drain. To charge the filter, immerse it in any suitable light oil as recommended in chapter 6 of the equipment instruction book.

If spare filters are available, use them in place of the dirty ones so that the blower motor will not pull outside dust and dirt into the equipment.

When replacing the filters, be sure that the air flow indicator arrow on the filter points toward the inside of the unit.

As any technician will tell you, moisture is a great danger to any electronic equipment. Therefore, you must make sure the filters are absolutely dry before replacing them. Filters usually dry thoroughly in about 12 hours.

Judging from the time required to clean a very dirty filter, you can see how important it is that filters are vacuumed often. The frequency for cleaning filters with a vacuum cleaner depends on the ship's operating schedule. For example, if your ship is undergoing extensive operations, the CIC will have more personnel, many of them smoking. Smoking causes cigarette ashes, plus dust and dirt from many feet, to be drawn into the filter by the blower motors. In such a case the filters should be cleaned at least three times a week. On the other hand, if your CIC is conducting normal or routine steaming, the personnel requirement is less and the filters would need to be cleaned only twice a week. If the CIC is seldom used, then the filters should be cleaned only once a week. In any event, the filters should be cleaned at least once a week.

CLEANING FERRULE RESISTOR AND FUSES

Remove ferrule-type resistors and fuses from their clips, and inspect both ends of the component and the clips for dirt and corrosion. Clean the contacts, using a cloth moistened with the Navy-recommended solvent. If the contacts are unusually dirty or pitted, notify the technician in charge of the equipment.

CLEANING PLASTIC WINDOWS

Clean plastic windows on both sides with lens tissue or with a clean, soft cloth free from abrasives. Do not use the brightwork polish, as it will scratch the soft plastic and leave a powdery film to clog gears and get between contacts.

CLEANING AND INSPECTING TUBES AND SOCKETS

While cleaning the equipment, all tubes should be checked to make sure they are firmly secured in their sockets and that the pins make good contact.

Wipe off all tube envelopes with a dry cloth. Make absolutely certain the high-voltage safety switches are off while working inside modulator units. Remember to short out the tube caps to ground with the shorting bar.

Check exposed plate and grid connections for corrosion or loose contacts. Inspect all tube sockets to ensure that they are held securely in place and that all connections are firm.

ELECTRICAL MEASURING DEVICES

One of the qualifications of the RD3 and 2 is to know how to use test equipment such as tube testers, multimeters, and output meters. These devices are required in operational and preventive maintenance of radar equipment and electronic countermeasures equipment. Let us first discuss a few more common meters and their uses.

BASIC METER

Electric meters are simple devices similar in appearance to the one shown in figure 11-3. There are many variations of these basic types, and as a Radarman, you will see and use some of them in your daily work. Outstanding features of a basic meter are its metal case (which may vary in size and appearance), printed scale, and pointer. The case contains the meter movement—the device that detects and measures electricity. Two terminals are used to connect the meter to whatever is being investigated. The scale is marked off in numbers to indicate

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electrical quantities, and the pointer moves across the scale to show how much electrical effect is taking place.

WHAT METERS MEASURE

Three factors control an electric circuit. They are current, electromotive force (voltage), and resistance.

In an electrical circuit there must be something to start electrons moving, such as a battery or a generator. There must be a path, or conductor, along which the stream of electrons may flow—a metal wire, for example. To cause this stream of electrons to flow, there must be an electrical force, called VOLTAGE. The intensity of the current is the rate of flow of the electrons; that is, the number of electrons passing a given point in 1 second (called the CURRENT instead of the intensity of the current). There will always be some resistance along the circuit to oppose the stream of electrons. This opposition is known as the RESISTANCE of the circuit.

Units of Measurement

Although the ampere is the basic unit of measurement for current flow, it is not always a convenient unit. Current flows seldom exceed 1000 amperes but may often be as little as 1/1000 ampere. Since current flow seldom exceeds 1000 amperes, the ampere can be used satisfactorily as the unit of measurement for currents in excess of 1 ampere. However, it is not convenient for measuring currents less than 1 ampere.

If current flow is between 1/1000 ampere and 1 ampere, the unit of measurement is the milliampere, which is equal to 1/1000 ampere. For current flow less than 1/1000 ampere, the microampere is the unit used; it is equal to 1/1,000,000 ampere. Meters for measuring milliamperes of current are called milliammeters, while those for measuring microamperes are microammeters. Units of measurements are subdivided in such a way that a quantity expressed in one unit may readily be changed to another unit, either larger or smaller, by moving the decimal point. For example, to change 35 milliamperes to amperes, move the decimal point three places to the left; thus, 35 milliamperes = 0.035 ampere.

How To Measure Current

When the amount of current flowing through a circuit is to be measured, the ammeter is

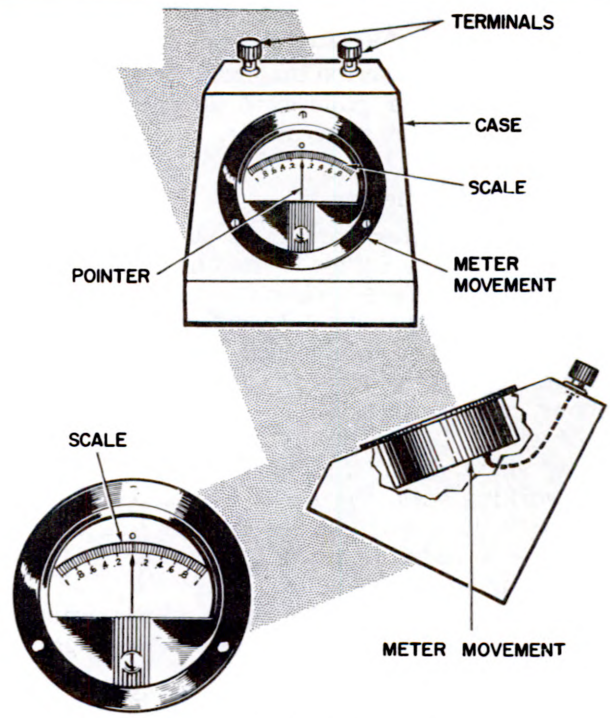

Figure 11-3.—Electric meter.

always connected in series with the line that delivers current to the circuit; it will be damaged if it is connected in any other way. Because an ammeter indicates the rate of electron movement, just as a meter in a water system shows the rate at which gallons of water are used, it follows that in order to show correctly the amount of current being used, the ammeter must be connected into the line (by breaking or opening the line to insert it). Illustrated in figure 11-4 are two circuits, one without the ammeter, and the other with the ammeter connected in series with line to measure lamp current. The pointer indicates on the meter scale the number of amperes of current flowing.

Alternating current (A-C) ammeters measure current that flows in both directions, while direct current (D-C) ammeters measure current that flows in only one direction. Current in

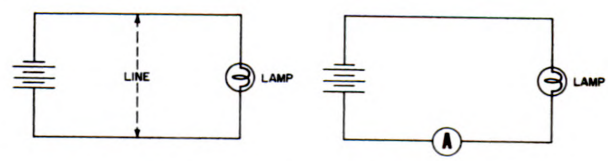

Figure 11-4.—Simple circuit with ammeter and without ammeter.

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either direction causes the meter pointer to swing upward on a D-C ammeter, but current in the wrong direction through a D-C ammeter causes the meter pointer to turn in the wrong direction, damaging the meter.

Multirange Ammeters

Some ammeters are built with a number of internal shunts, with a switching arrangement to parallel different shunts across the meter movement to measure different currents. Thus, a single meter movement can serve as a multirange ammeter. A scale for each range is shown on the meter face.

Figure 11-5 is one type of meter found on many ships. Even if it is not the type you will be working with, the basic principles are the same. It is a multipurpose meter and can be used as a voltmeter, a milliammeter, an ohmmeter, or an output meter.

To use the equipment as a milliammeter, first plug the two test probes into the negative and positive spaces provided.

Snap the 3-position switch located on the lower left side of the equipment to either A-C or D-C, depending on whether you are to measure alternating or direct current. Next, place the range selector switch to either 250 MICROAMPS, 500 M.A., 100 M.A., or 10 M.A. as required.

When measuring an unknown current with a multirange ammeter, the highest range is always tried first, then the next highest range, and so on until the needle is positioned about midscale. In this way you can be assured that the current is not excessive for the meter range, and you will never have the unfortunate experience of burning out a meter movement or wrapping the needle around the stop-peg.

An ammeter, of course, measures CURRENT. All the current you expect to measure must flow through the meter. The ammeter must therefore be connected in SERIES with the other circuit elements, as shown in figure 11-4, NOT in parallel. Using figure 11-4, assume the battery has a value of 6 volts. The ammeter is connected in series with the line to measure the pilot lamp current. With the multipurpose meter switch in the D-C position and the range selector switch at 10 M.A., the needle swings just beyond the halfway point to the number 6 of the second scale from the top on the meter. Thus, the lamp is drawing 6 milliamperes of current. Notice the two separate current scales, one for A-C and one for D-C. It is important to use the correct scale. In this example you would use the second scale from the top (marked D-C) and the last set of numbers in that scale. Notice the second scale has values of 250 microamps (read directly, not as a decimal value) or 500 M.A. (indicated as 50 on the scale), or 100 M.A. (indicated as 10 on the scale). In the 10 M.A. range the scale is read directly 0 to 10 M.A. The scale to be used, of course, depends on the switch setting.

Figure 11-5.—Multirange ammeter.

Units of Voltage Measurement

Measurement of the electromotive force between two unequal charges is usually in volts, but when the difference in potential is only a fraction of a volt, or more than 1000 volts, measurement is in other units. For voltages less than 1 volt, millivolts and microvolts are

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used, just as milliamperes and microamperes are units for measuring currents under 1 ampere. While current seldom exceeds 100 amperes, voltage often exceeds 1000 volts, so that the kilovolt—equal to 1000 volts—is the unit of measurement. When the difference in potential between two charges is between 1/1000 volt and 1 volt, the millivolt is the unit of measurement; when it is between 1/1,000,000 volt and 1/1000 volt, the unit is the microvolt.

Meters for measuring voltage have scale ranges in microvolts, millivolts, volts, and kilovolts, depending on the units of voltage to be measured.

Units of voltage measurement are changed the same way that units of current are changed. However, kilo is now used to express voltage. As a result, you need to know how to convert kilovolts to volts and vice versa. To change kilovolts to volts, the decimal point is moved three places to the right; to change volts to kilovolts, it is moved three places to the left. For example, 5 kilovolts equal 5000 volts (the decimal point is after the 5). Three zeros are added to provide the necessary places.

How To Measure Voltage

An ammeter measures the current moving through a material. Since current flow varies with voltage difference, a greater current flow indicates a greater voltage difference. Voltage is measured by a voltmeter, which indicates the current flow in a given material called a multiplier resistor. The meter movement and multiplier are always connected in series, and the series circuit is then connected in parallel with the circuit across which the voltage is measured. For a given multiplier, the meter will indicate a large current if the voltage is high; a small current if the voltage is low. Because the current through the meter is proportional to the voltage across the meter and multiplier, it is possible to calibrate the scale in volts.

The multiplier resistor determines the scale range of a voltmeter. Since the multiplier is built into most of the voltmeters you will use, you can measure voltage by making very simple connections. When the plus (+) meter terminal is connected to the plus terminal of the voltage source, and the minus (-) meter terminal to the minus terminal of the voltage source, with nothing else connected in series, the meter reads voltage directly. This is illustrated in figure 11-6. Notice particularly that the negative side of the voltmeter is connected to the negative side of the battery from which the voltage is to be measured, and the positive side of the voltmeter is connected to the positive side of the battery. If these connections are reversed, the meter needle will move to the left of the zero mark, and a reading cannot be obtained.

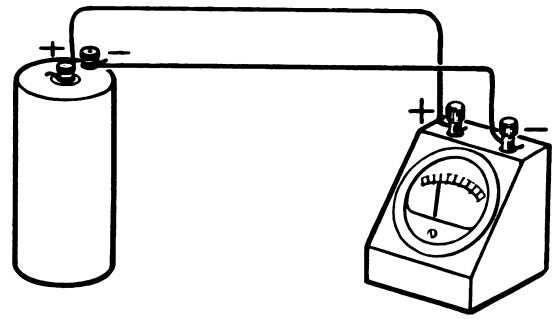

Figure 11-6.—Connect a voltmeter plus to plus, minus to minus.

Figure 11-7 shows how the voltmeter is used to measure the voltage drop across a load. The negative lead is connected to the side of the load into which the electrons enter (the minus side), and the positive lead is connected to the side of the load from which the electrons emerge (the plus side).

Voltmeters, like ammeters, are made for use on only one kind of electricity, either A-C or D-C. Polarity must be observed with D-C voltmeters, but not with A-C voltmeters.

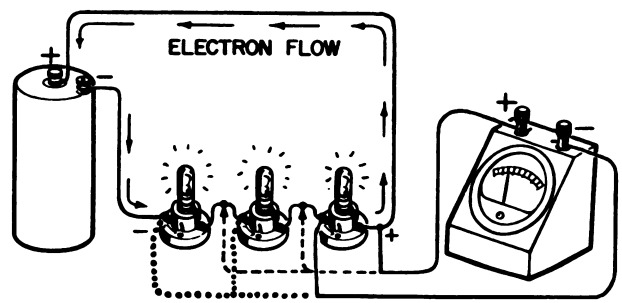

Figure 11-7.—How to connect a voltmeter across a load.

Multirange Voltmeters

Range of any voltmeter can be increased by the addition of a multiplier to the voltmeter circuit, in series with the basic meter movement.

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The multiplier causes reduction of the deflection of the pointer on the meter. By using multipliers of known values, the deflection can be reduced as much as desired.

Multirange voltmeters are physically similar to ammeters. Their multipliers usually are inside the meter, with suitable switches or sets of terminals on the outside for selecting range. Proper range is selected by starting with the highest range and working downward until the needle reads about midscale.

Because they are lightweight, portable, and can be set up for different voltage ranges by the flick of a switch, multirange voltmeters are extremely useful. Figure 11-8 shows a 3-range multirange voltmeter.

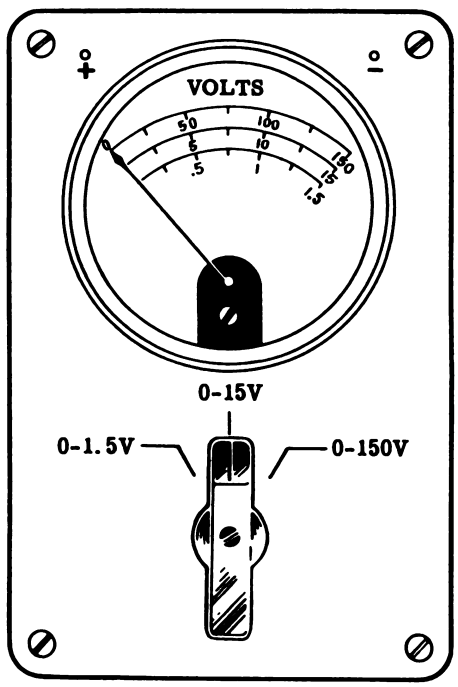

Figure 11-8.—Typical 3-range multirange voltmeter.

Units of Resistance

When 1 volt causes 1 ampere of current flow, the resistance is 1 ohm. The ampere is the unit of measurement for current; the volt is the unit of measurement for voltage. These units are necessary in order to compare different currents and different voltages. In the same manner, a unit of measure is needed to compare the resistance of different conductors. The basic unit of resistance is the ohm, equal to that resistance which will allow exactly 1 ampere of current to flow when 1 volt of emf is applied across the resistance.

Small values of resistance are expressed in microhms, and very large values in megohms. One microhm equals 1/1,000,000 ohm, while 1 megohm equals 1,000,000 ohms.

Units of resistance are converted the same way units of current or voltage are changed. To change microhms to ohms, the decimal point is moved six places to the left; ohms to microhms, six places to the right. To convert megohms to ohms, the decimal point is moved six places to the right, and to change ohms to megohms, it is moved six places to the left.

For resistance between 1000 ohms and 1,000,000 ohms, the unit of measurement is the kilohm (abbreviated K), which is written 10K and equals 10,000 ohms. To change kilohms to ohms, the decimal point is moved three places to the right. The decimal point is moved three places to the left when converting ohms to kilohms.

The Ohmmeter

Meters for measuring resistance are called ohmmeters. They differ from ammeters and voltmeters particularly in that scale divisions are not equally spaced, and a built in battery is required for proper operation. When using the ohmmeter, no voltage should be present across the resistance being measured except voltage of the ohmmeter battery; otherwise, the ohmmeter will be damaged.

Ohmmeter ranges usually vary from 0-1000 ohms to 0-10 megohms. The accuracy of the meter readings decreases at the maximum end of each scale, especially for the megohm ranges, because the scale divisions become so closely spaced that an accurate reading cannot be obtained. Unlike other meters, the zero end of the ohmmeter scale is a full-scale deflection of the meter pointer. (See fig. 11-9.)

Special ohmmeters, called meggers, are needed for measuring values of resistance over 10 megohms, because the voltage required is very high for ranges above 10 megohms. Some meggers use high-voltage batteries to obtain the necessary voltage. Others use a special type of hand generator. While ohmmeters are used to measure the resistance of conductors, the most important use for meggers is to measure and test insulation resistance.

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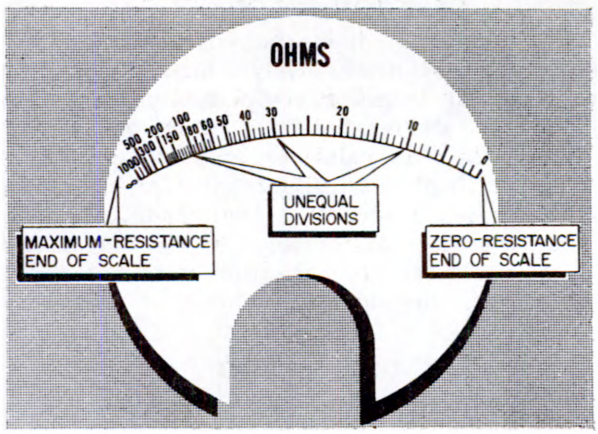
OHMS
500 200 100 80 60 50 40 30 20 10 0
1000 300 150
UNEQUAL DIVISIONS
MAXIMUM-RESISTANCE END OF SCALE
ZERO-RESISTANCE END OF SCALE

Figure 11-9.—Ohmmeter dial scale.

READING METER SCALES

When using a meter to determine whether equipment is working properly, or when working with an ET to find out what is wrong with equipment (troubleshooting), or when taking readings for daily checks, etc., meter readings must be very accurate.

Many factors can cause meter readings to be inaccurate, and it is necessary to keep them in mind when using a meter. You will find that the usable range of a meter scale does not include the extreme ends of the scale. For nearly all meters, the most accurate readings are those taken near the center of the scale. When current is measured with an ammeter, milliammeter, or microammeter, the range of the meter should be chosen to give a reading as near midscale as possible.

Not all meters can be used in both horizontal and vertical positions. Due to the mechanical construction of many meters, accuracy of readings will vary considerably with the position of the meter. Normally, the panel-mounting type of meters on radar equipment are calibrated and adjusted for use in a vertical position. Meters in many test sets and in some electrical equipment are made for the horizontal position.

A zero set adjustment on the front of the meter is for setting the meter needle at zero on the scale when no current is flowing. This adjustment is made with a small screwdriver, and should be checked when using a meter, particularly if the vertical or horizontal position of the meter is changed. Some radar equipments have the same adjustment, but it should never be made by anyone except a qualified technician.

Meter scales to measure current are equally divided with a usual total of 30 to 50 divisions. The meter should always be read from a position looking straight at the meter face. Meter divisions are small, and the meter pointer is raised above the scale, so that reading the pointer from any other position would result in an inaccurate reading, often as much as an entire scale division. This type of incorrect reading is called parallax. Because most meters are slightly inaccurate on account of the meter construction, an additional error from a parallax reading could result in a very inaccurate reading.

When the meter pointer reads a value of current between two divisions of the scale, usually the nearest division is taken as the meter reading. If a more accurate reading is desired, the position of the pointer between the divisions is estimated, and the deflection between the scale divisions is added to the lower scale division. Estimating the pointer position is called interpolation.

Usable Meter Range

The range of an ammeter indicates the maximum current that can be measured with the meter. Current in excess of this value will cause serious damage to the meter. If an ammeter has a range of 0-15 amperes, it will measure any current flow not exceeding 15 amperes. A current greater than 15 amperes will damage the meter.

While the meter scale may have a range of 0-15 amperes, its useful range for purpose of measurement will be from about 1 ampere to 14 amperes. When this meter scale indicates a current of 15 amperes, the actual current through the meter may be greater than 15 amperes because the meter can indicate only its maximum range. For that reason, the useful maximum range of any meter is slightly less than the maximum range of the meter scale. A current of 0.1 ampere on this meter scale would be difficult to read since it would not cause the meter needle to move far enough from zero to obtain a definite reading.

Smaller currents, such as 0.001 ampere, would not cause the meter needle to move, therefore could not be measured at all with this meter. The useful minimum range of a meter never extends down to zero, but only to the point at which the reading can be distinguished from zero.

Ammeter ranges are usually in multiples of 5 or 10; that is 0-5 amperes, 0-50 amperes, etc.

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Ranges above 0-100 amperes are not common, because currents in excess of 100 amperes are seldom used.

Do not get the idea that this emphasis on accuracy applies only to test equipment. There are routine meter checks that must be performed by every radar operator, and they must be conducted with care and accuracy. If you do them properly, there will be much less need for going into the equipment with the test equipment discussed so far. For example, a routine check of the magnetron current is conducted periodically on almost all radar sets. With the main power on and the radar set control in the radiate position, the transmitter current must be checked. Meter readings should be steady and in the GREEN (normal) portion of the scale. Otherwise, the main power switch should be turned to standby. The regulated voltage should also be checked periodically. The regulated voltage for reading each set should be known by the radar operator. If the regulated voltage is not within proper boundaries, the set is not working properly and troubles can be expected.

RESISTORS

To conduct preventive maintenance on equipment safely and properly, it is necessary to know a good deal about resistance and resistors. The best way is to learn the construction and properties of resistors and the method of determining their values.

There is a certain amount of resistance in all of the electrical equipment you operate. Sometimes this resistance is not sufficient to control the flow of current to the extent desired. When additional control is required—for example, when starting a motor—resistance is purposely added to that of the equipment. Devices used to introduce extra resistance are called resistors.

Radar equipments utilize a wide variety of resistors. Some have a fixed value; others are variable. All resistors are of special resistance wire, graphite (carbon) composition, or metal film. Wire-wound resistors are usually for controlling large currents, while carbon resistors control currents which are relatively small.

There are too many types of resistors to describe them in the limited space of this text. However, by reading and studying *Basic Electricity* and *Basic Electronics*, to supplement this text, you will learn practically all that a Radarman needs to know about resistors.

RESISTOR COLOR CODE

In the event that you have to replace a resistor, you must always make sure of the value of the resistor you plan to use. Resistor values are designated by a color code system. This system is relatively easy to memorize. Appendix III of *Basic Electricity* has a complete and detailed instruction for reading and determining the resistor value by the color painted on the resistor. The capacitor color code is also explained in the same appendix.

TUBE TESTING

In addition to routine maintenance and cleaning of equipment, the operator should be familiar with the location and function of fuses, blown fuse indicators, and tubes.

Radar casualties consist mainly of tube failures. Tube failures may be low emission, open filaments, shorted element, gassy tube, and miscellaneous casualties of less frequent occurrence. Knowing the location of tubes, and their function, the operator can make emergency replacement of blown fuses and defective tubes.

In section 5 of the equipment instruction book, you will find a step-by-step troubleshooting procedure chart, like the one shown in figure 11-10, to aid the operator in locating and effecting emergency equipment repairs. If the operating procedure outlined in section 4 of the instruction book is being followed, and the equipment is not operating properly, CALL THE TECHNICIAN AT ONCE. If he is not available, and the equipment is required for immediate use, then the operator should attempt to restore normal operation by using the troubleshooting procedure given in section 5 of the instruction book.

In carrying out his maintenance responsibilities, the operator may be called on to test electron tubes. This part of the preventive maintenance program should ensure that spare tubes are available when needed.

Spare vacuum tubes sometimes will not operate satisfactorily in the equipment for which they are provided. It is necessary, therefore, that all spare tubes be tested in the sockets where they are to be used. This test should include operating the tubes for a period of perhaps 50 hours. Tube sockets should also be checked at the same time. Satisfactory tubes should be labeled "Equipment tested spare." Tubes which fail to give satisfactory performance in one application should not be discarded. They may function well in a less critical application.

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Vacuum tubes normally are tested by any one of many standard tube testers. It is impractical to discuss the merits of all the tube testers. In spite of the many types, they are quite similar and relatively simple to use. Have your ET check you out in how to operate your ship's particular type of tube tester.

Tube testers are fairly accurate, but may not always provide a correct indication of the condition of a tube. For instance, a tube usually does not fail instantly. Weakness of a tube may proceed gradually and not become apparent in the tube tester. This is because the signal applied to the tube in the tester is a 60-cycle sine wave,

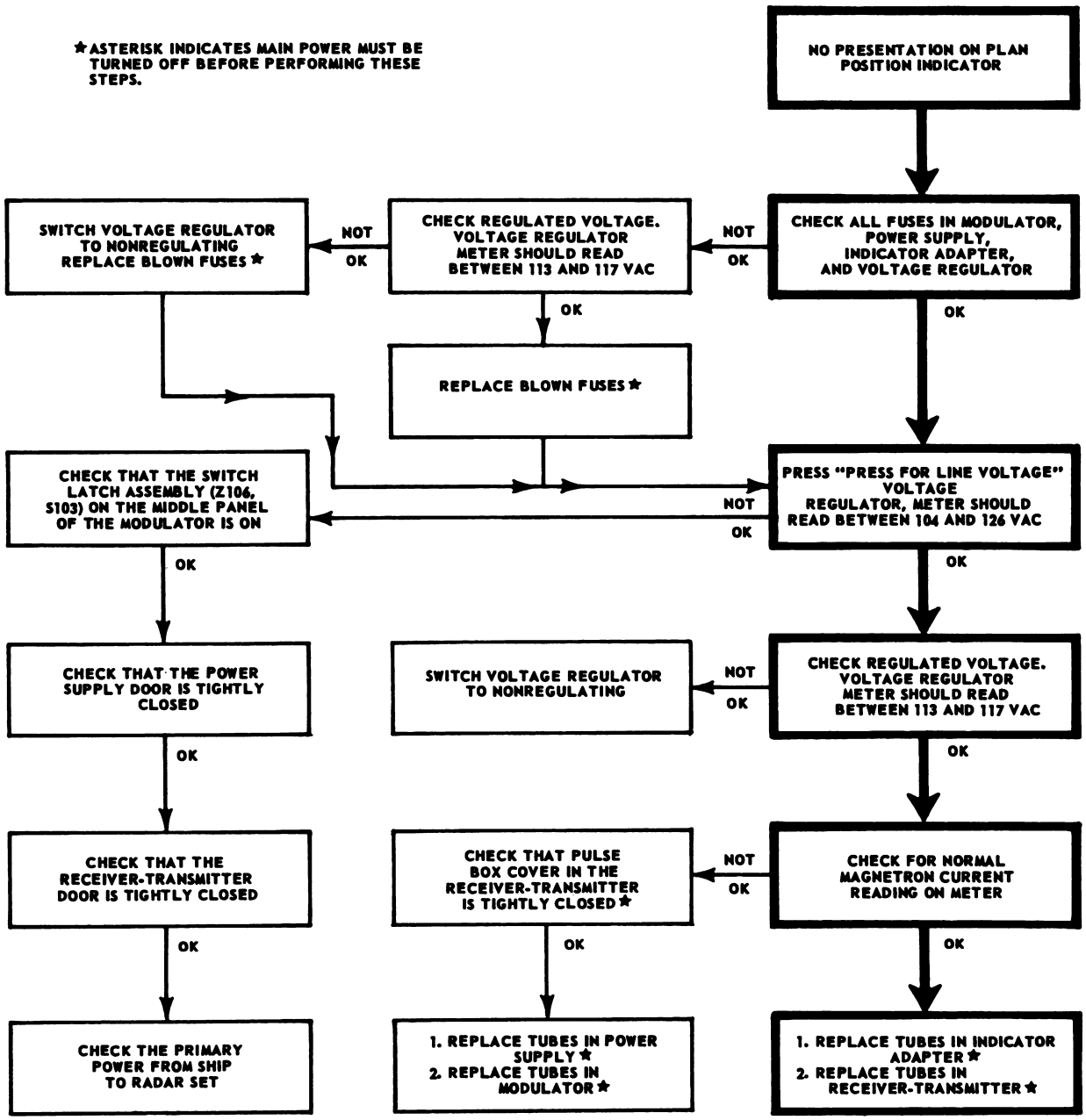
★ASTERISK INDICATES MAIN POWER MUST BE TURNED OFF BEFORE PERFORMING THESE STEPS.
NO PRESENTATION ON PLAN POSITION INDICATOR
CHECK ALL FUSES IN MODULATOR, POWER SUPPLY, INDICATOR ADAPTER, AND VOLTAGE REGULATOR
NOT OK
OK
CHECK REGULATED VOLTAGE. VOLTAGE REGULATOR METER SHOULD READ BETWEEN 113 AND 117 VAC
NOT OK
SWITCH VOLTAGE REGULATOR TO NONREGULATING REPLACE BLOWN FUSES ★
OK
REPLACE BLOWN FUSES ★
PRESS "PRESS FOR LINE VOLTAGE" VOLTAGE REGULATOR, METER SHOULD READ BETWEEN 104 AND 126 VAC
NOT OK
CHECK THAT THE SWITCH LATCH ASSEMBLY (Z106, S103) ON THE MIDDLE PANEL OF THE MODULATOR IS ON
CHECK REGULATED VOLTAGE. VOLTAGE REGULATOR METER SHOULD READ BETWEEN 113 AND 117 VAC
NOT OK
SWITCH VOLTAGE REGULATOR TO NONREGULATING
CHECK THAT THE POWER SUPPLY DOOR IS TIGHTLY CLOSED
CHECK FOR NORMAL MAGNETRON CURRENT READING ON METER
NOT OK
CHECK THAT PULSE BOX COVER IN THE RECEIVER-TRANSMITTER IS TIGHTLY CLOSED ★
CHECK THAT THE RECEIVER-TRANSMITTER DOOR IS TIGHTLY CLOSED
1. REPLACE TUBES IN INDICATOR ADAPTER ★
2. REPLACE TUBES IN RECEIVER-TRANSMITTER ★
1. REPLACE TUBES IN POWER SUPPLY ★
2. REPLACE TUBES IN MODULATOR ★
CHECK THE PRIMARY POWER FROM SHIP TO RADAR SET

Figure 11-10.—Sample troubleshooting procedure.

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whereas, in actual practice, the electronic equipment may be subjected to all kinds of wave shapes and frequencies that vary from a few cycles to several billion cycles per second. The shipboard tube tester cannot determine accurately the ability of a tube to act as an oscillator or as an ultrahigh frequency amplifier. Therefore, many tubes which check OK in a tube tester may not perform properly in actual service. Similarly, some tubes which operate satisfactorily in service may check bad in a tester.

RADAR INSTRUCTION BOOKS

Accompanying each radar aboard ship is an instruction book prepared by the manufacturer of the radar. The manual contains pertinent instructions for operation and maintenance of that particular set. Exact details are given for cleaning and oiling the gear, and various safeguards to observe while working on the equipment are pointed out. Also discussed are detailed instructions for correcting radar failures and poor performance.

Take every opportunity to study and familiarize yourself with the manual dealing with the radar you will be operating and the equipment to which you will be assigned for maintenance.

Manufacturers' instruction books usually have eight sections as follows:

1. General Description;
2. Theory of Operation;
3. Installation;
4. Operation;
5. Operator's Maintenance;
6. Preventive Maintenance;
7. Corrective Maintenance;
8. Parts List.

You will be concerned principally with sections 4 and 5. These are written primarily for operators; remaining sections are for technicians.

In section 4 you will find detailed instructions for turning on the equipment, securing it, the tuning procedure, and checks to be made while operating.

Section 5 deals with operator's maintenance. This section has two main divisions—routine maintenance and emergency maintenance.

ROUTINE MAINTENANCE

Routine maintenance is divided into two groups: electrical and mechanical. Remember that operating personnel should not attempt any extensive or complicated repairs. Routine checks, consisting of tests to determine whether the equipment is performing satisfactorily, and mechanical inspection to determine the general condition of the equipment, should be made at the beginning of each watch. Data such as meter readings, pulse length, repetition rate, and the bandwidth selected may be recorded in a daily log.

Tables in the instruction book list a number of electrical checks that should be made at the beginning of each watch. When making these checks, certain precautions must be observed. A few of them follow.

1. Do not take high-voltage readings until the radar has been in operation long enough to ensure that there can be no further arcing in the magnetron.
2. Do not measure frequency or ring time until the radar has been operating for an hour or more and has stabilized.
3. When measuring the standing wave ratio, adjust the depth of the traveling probe for a minimum meter indication.

At the beginning of each watch, check all visible assembly bolts, studs, and screws on the exterior of various units. Usually a cursory examination will disclose anything of unusual nature, and the entire procedure will require little time. Pay particular attention to the bonding on the shock mounts, because it is always possible that the bonding might have become frayed or damaged in cleaning. The condition of all cabling should be checked periodically, and any repairs or replacements indicated should be reported immediately. Examine the panel thumbscrews that hold the units in the cabinets. If a unit is loose in its cabinet, the roll of the ship might cause it to slide out until stopped by the latches, in which case the interlocks would open and the equipment would not operate. The paint on the various components should be examined, and any scratches or corrosion reported.

Following inspection of the thumbscrews and paint, inspect the control knobs to make sure that none of them are broken or loose on their shafts, and that the control shafts are not bent. Check the units that have locks on their control knobs to see that the locks are in good condition and that none of them have become loosened. A loose lock may mean that the control is out of adjustment, and this should be determined as soon as the equipment is first energized. Observe each fuse warning lamp to ensure that all fuses are in good working order. If viewing shields are used on any of the indicators, check their condition

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to see that they fit properly and securely.

Notice the action of all switches when the equipment is turned on to determine whether they are in good condition or in need of replacement. Check the action of all operating controls to make certain that they function correctly.

EMERGENCY MAINTENANCE

If trouble is experienced while operating the equipment, make sure that the correct operating procedure is being followed (check the operation section of instruction book) before assuming that the equipment is faulty. If trouble persists after checking the operating procedure, the operator should call a technician at once. Under battle conditions, however, it may be necessary for the operator to make certain repairs. Emergency repairs that may be made by operating personnel include replacing fuses, indicator lamps, tubes, and crystals.

POMSEE PROGRAM

POMSEE is the abbreviation for Performance, Operational, and Maintenance Standards for Electronic Equipment.

Perhaps you have been aboard ship and have been overwhelmed by maintenance problems. The Bureau of Ships is well aware of your plight. Some of the most persistent complaints received in BUSHIPS from the fleet and from the field concern the difficulties of maintaining electronic equipment. Whether the basic cause is complexity or numbers of equipment, shortage of technical personnel or repair parts, or lack of training or organization, the problem is serious and a difficult one to combat.

The POMSEE program is one approach which should bring the electronic operational maintenance problem into clearer focus. POMSEE stresses simplification. The POMSEE program is based on the knowledge that operational maintenance of electronic equipment is simplified if the man supervising and the man carrying out the maintenance know exactly what to do and when to do it. BuShips has undertaken, in effect, to supplement existing instruction books and technical manuals with two separate publications—Performance Standards Sheets and Maintenance Standards Books.

PERFORMANCE STANDARDS SHEETS

Performance Standards Sheets are prepared by BuShips for each piece of electronic equipment. They are filled out by the engineers when the equipment is installed or just after being overhauled. A minimum value is set up by the Bureau for certain performance characteristics which must be obtained before the equipment is considered satisfactory. Such data as minimum discernible signal, power output, and the range at which certain types of targets should be picked up are entered on the Performance Standards Sheets.

Performance Standards Sheets usually are in two parts: Operational Performance, and Standards for Equipment Measurements.

Much of the information contained in some of the Performance Standards Sheets is of a nature affecting the national defense of the United States, and so are classified Confidential. If a classified sheet were placed in a Maintenance Standards Book, this would make the book classified. Because each ship has a large quantity of electronic equipment, a stowage problem would result from classified Maintenance Standards Books. The Performance Standards Sheets are therefore placed in a common binder, Binder for Electronics Equipment Performance Standard Sheets (NavShips 93000). Thus, the problem of classified stowage is solved by declassifying the Maintenance Standards Books and placing all classified material in one binder.

MAINTENANCE STANDARDS BOOKS

Maintenance Standards Books provide standard methods for taking measurements that affect the performance of a specific equipment, a space to record such measurements, and a preventive maintenance schedule for the equipment.

Maintenance Standards Books are in two parts: Part I—Test Procedures and Maintenance References, and Part II—Preventive Maintenance Checkoff.

Part I—Test Procedures and Maintenance References

Part I of the Maintenance Standards Books (Test Procedures and Maintenance References) contains itemized, step-by-step procedures which determine whether the particular set or equipment and its critical circuits and components are operating at peak performance. Upper and lower limits or tolerances are given for each step so that an indication is readily available if performance falls below standard and

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investigation of the cause is necessary. (No attempt is made in the Performance Standards Book to tell how to locate the trouble.)

Part II—Preventive Maintenance Checkoff

Preventive maintenance checkoff procedures require that standard tests be performed at regular intervals on circuits and components, and specify what and when other routine maintenance (such as lubrication) is to be accomplished. Maintenance checkoffs are for less experienced electronics technicians or strikers and for the operator who may not have received formal training on the set he is required to maintain. With these maintenance checkoffs, supervisory personnel, officers, and leading petty officers should be in a better position to insist that routine checks and routine preventive maintenance are made. If preventive maintenance is not done, it should not be for lack of knowledge of work required. All of the daily tests and some of the weekly tests prescribed should be performed by the operators in order to relieve the overworked technicians of some of their more routine duties. The individual ship's electronics officer should determine who should undertake the routine tests.

KEEPING RECORDS

An example of a daily checkoff form for Radar Set AN/SPS-10 is given in figure 11-11. Notice that the top right side of the illustration has space for listing any test equipment required to perform the check. At the top left is a list of operating conditions and control settings, such as whether the radar should be off, on, or radiating; and the position for setting the radar set controls. These apply to the entire page unless other conditions and settings are given for some of the procedure steps.

Procedure step numbers are encircled for easy tie-in with their corresponding step numbers on the accompanying illustrations of equipment setups. Arrows leading from a given step number on the illustration graphically present certain basic information given in the associated step of its accompanying chart, as follows: the point where the test equipment is to be connected; the setting of the pertinent control or switch; and the indicator from which the test reading is to be taken.

Each chart is a self-explanatory page next to the illustration to which it pertains, and lists step-by-step procedures for conducting a test. It also contains the reference standards previously entered by one of the ship's ET's.

A distinction between performance standards and reference standards should be pointed out at this time.

Performance standards set forth in the Performance Standards Sheets must be met when the equipment is installed. When it has been established that the equipment meets the performance standards, the reference standards are taken by a qualified person and are entered in ink in the Reference Standard column of Part I of the Maintenance Standards Book.

Upon completing each check prescribed, the results should be entered in the time schedule tables (see fig. 11-11) accompanying the charts. By using both sides of the time schedule table, a 2-year record of each step or group of steps can be kept. Entries in the tables are of prime importance, for they indicate whether the equipment is performing at maximum efficiency. Comparison of a given reading with readings previously obtained, and with the initial maintenance standard test indications (Part I), will reveal any significant change. It is expected that readings will show some changes from time to time. This does not necessarily mean that the equipment is not operating properly. If, however, any particular step (ring time, for example) shows a reading which varies progressively in the same direction every time the check is made, it is an indication that the equipment is not in top condition and a failure is about to occur, and corrective measures should be taken.

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NAVSHIPS 91921.42 Part II—Daily

AN/SPS-10

Step 1

PART II—PREVENTIVE MAINTENANCE CHECK-OFF

Operating Conditions and Control Settings:

MAIN POWER switch (S501): RAD
AFC switch (S502): ON
STC switch (S503): OFF
ANTI-JAM switch (S504): OFF
BCN-RADAR switch (S505): NLP

Test Equipment Required:

None

STEP		PROCEDURE
NO.	ACTION REQUIRED	
1	Record echo box ringing time.	Perform step 7 of Section D, Part I. Obtain proper indication and record. When in port, see page vii.

Time Schedule: Record and initial.

Approx Time Reqd for Daily Check—15 min

1st Year of Operation

Day	19___	19___	19___	19___	19___	19___	19___	19___	19___	19___	19___	19___
1												
2												
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31												
Initial												

Figure 11-11.—Example of a daily preventive maintenance check.

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QUIZ

1. What two general categories of ratings are responsible for the proper performance of electronic equipment?
2. Under what heading are radar operator responsibilities toward his equipment?
3. Why is it important that switches be tagged after you turn off the power?
4. What precaution must be taken before handling a capacitor even if you know the power is secured?
5. What method is recommended for cleaning the inside of a cabinet?
6. Why should solvents be used sparingly?
7. Why is it important to vacuum air filters frequently?
8. What three things do meters in an electrical circuit measure?
9. In what section of the equipment book will you find detailed instructions of the sequence of turning on the equipment, securing it, tuning procedures, and checks to be made while operating?
10. What is a good reference for operator maintenance of specific equipment?
11. The Navy has set up a program of preventive maintenance which, when followed closely, will keep equipment at peak performance and cut down the number of failures. What is this program called?

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CHAPTER 12

TELEPHONE AND TALKING PROCEDURES

INTRODUCTION TO CIC COMMUNICATIONS

This chapter will give you an overall picture of the various methods of communication in CIC. External communications are covered in *Radarman 3 & 2*, Volume 2, and will not be discussed here. Instead interior communication methods, code words, and procedures will be covered.

First, we want to stress the necessity for SPEED. Speed is the essence of all communication in CIC. Accuracy, reliability, and security are equally important. But unless our information and orders are handled so that action may be taken in sufficient time to be completely effective, our effort will be wasted. So bear in mind that while accuracy, reliability, and security of communications are essential, SPEED is our ultimate goal. Another point: you may be outstanding in your ability to perform a particular job in CIC, but unless you also are an expert in communications, your overall usefulness will be less than satisfactory.

The success of all CIC operations depends upon TEAMWORK. What is teamwork? The coordinated action of two or more individual members of a team. How do we achieve this coordinated action? By being able to exchange ideas, information, orders, and thus letting one another know what we are doing or plan to do. Without communications, the CIC team is not a team but, merely a group of men doing different jobs with individual skill but without the means for carrying the ball across the goal line. Remember this: every member of the CIC team must become an expert in voice communications.

THE NATURE OF CIC COMMUNICATIONS

Almost all CIC communications are tactical or operational in nature. By that we mean they are concerned with naval operations which are taking place now—at this instant—or will take place in the immediate future. CIC is not directly concerned with administrative communications. These are handled by the communication division on board ship. Since almost all of CIC's communications deal with immediate operations, the need for speed, reliability, and accuracy is plain. Let us take, for example, a typical case involving the speed of aircraft.

A plane traveling at the rate of 600 miles per hour will cover 10 miles each minute. Suppose the plane is detected at 100 miles and is heading directly toward the ship. Since the plane is traveling at the rate of 10 miles per minute, it will be overhead in 10 minutes.

Due to the fact that radio waves travel 186,000 miles per second, detection of a plane by radar can be considered instantaneous. When a radar operator detects a plane 100 miles away, it actually is at that point; there is no delay of information by radar to the radar operator. It follows, then, that any delay in taking action will be introduced by the system handling the information.

It is possible for friendly planes to leave a patrol station overhead at the exact instant of detection and, traveling at the same rate of speed, 600 miles per hour, intercept the detected plane 50 miles away.

This is not practical, however, because before the friendly planes can leave their patrol station to make the interception, they must receive an order to do so.

Now let's trace the paths along which radar information normally would travel. First, radar information goes from the radar operator to the CIC plotter. From CIC it goes to command and control stations throughout the ship and to the OTC and all other ships in the formation. The order to make the interception goes from the OTC or air defense ship to the air control ship. The air control ship then passes to the friendly planes the course and speed to take to make the interception.

What would be the delay between receiving the information and directing the planes to make the interception? Would it be 1 minute, 2 minutes, or 10 minutes? Suppose the CIC team is

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very efficient, there is perfect coordination among all CIC teams in the formation, and the delay caused by the methods of handling the information is 2 minutes. In that time the detected plane has traveled 20 miles and is 80 miles away. Possibly, the friendly planes can make the interception at about 30 or 35 miles away. This can be done only if the air controller gives the friendly planes the correct course to steer and the visibility is good enough for the friendlies to see the detected planes at a great enough range.

Let us say, on the other hand, that the CIC team is not so good and the delay is 10 minutes. You can see that it would be impossible to obtain an interception at a safe distance away from the force. Suppose the transmission from the air controller to pilot was garbled, and had to be repeated causing unnecessary delay, or the heading the plane is ordered to fly is incorrect, it stands to reason that reliability and accuracy are equally important.

CIC COMMUNICATION METHODS

How is it possible to achieve teamwork in communications? There must be reliable communications for passing information instantly to all who need it. The Radarman who gets a contact on the radarscope must have a means of sending data immediately to CIC. CIC, in turn, must plot and evaluate the information, then transmit it without delay to bridge, commanding officer's tactical plot, flag plot, gunnery control, and other interested stations throughout the ship. The radar operator uses sound-powered telephones for this purpose, while CIC uses both sound-powered telephones and interstation MC equipment. To use equipment properly calls for a knowledge of its construction and principles of operation. To be sure that the proper stations get the information, you must know what circuits to use, the purpose of each circuit in CIC, and which stations you can communicate with on each circuit.

MC SYSTEMS

Briefly, a standard shipboard MC station unit consists of a metal case enclosing an electronic speech-amplifier, with a control panel on the front (fig. 12-1). The control panel contains a speaker which serves as both loudspeaker for reception (marked REPRODUCER in illustration) and a microphone for transmission. Station selector switches on the control panel enable the operator to select any one of ten stations for transmission of a message simply by throwing ON the proper switch, which has the station identification on a small plate and a small red signal light next to it. Or, if the operator desires, he may select any combination of switches, up to ten, for simultaneous transmission to the desired number of stations. The control panel also includes on-off switches for both main and emergency sources of electrical power, with signal lights to indicate whether power is turned on or off; a main press-to-talk switch (marked TALK KEY on illustration) with a signal light (output lamp) to indicate that the transmission actually is going out; and a volume control for control of the local amplification.

As an illustration of the operation of an MC unit, assume you are in CIC and want to call conn. You first throw the station selector switch marked CONN; if the red signal light next to the conn switch begins to flash, you know the station is busy. If it is a steady light you know the line is clear for your message. When you throw the selector switch (assuming now that the line is clear) a steady red light will appear next to the CIC switch at the conning station. To answer you, the operator at conn throws the CIC switch and the signal lights at both stations begin to flash. Any other station attempting to cut in gets a flashing, busy signal.

In spite of this system's obvious advantage, when MC's are used as the primary means of internal communications, the noise level in CIC is greatly increased. The system is robbed of its value as an alarm to attract attention if other than urgent information is passed over it. Therefore, the MC units in CIC are to be used only for initial contact reports or other emergency communications. A list of a few of the MC systems, some not located in CIC, that you will see and use are:

General Announcing System, 1MC

This system is found on practically all ships, large or small. The system's transmitter is not located in CIC, but you may have occasion to use it while standing in-port quarter deck watches. It is used for passing general orders. Transmissions can be made from key stations, such as bridge, quarter deck, and damage control station to all compartments within the ship

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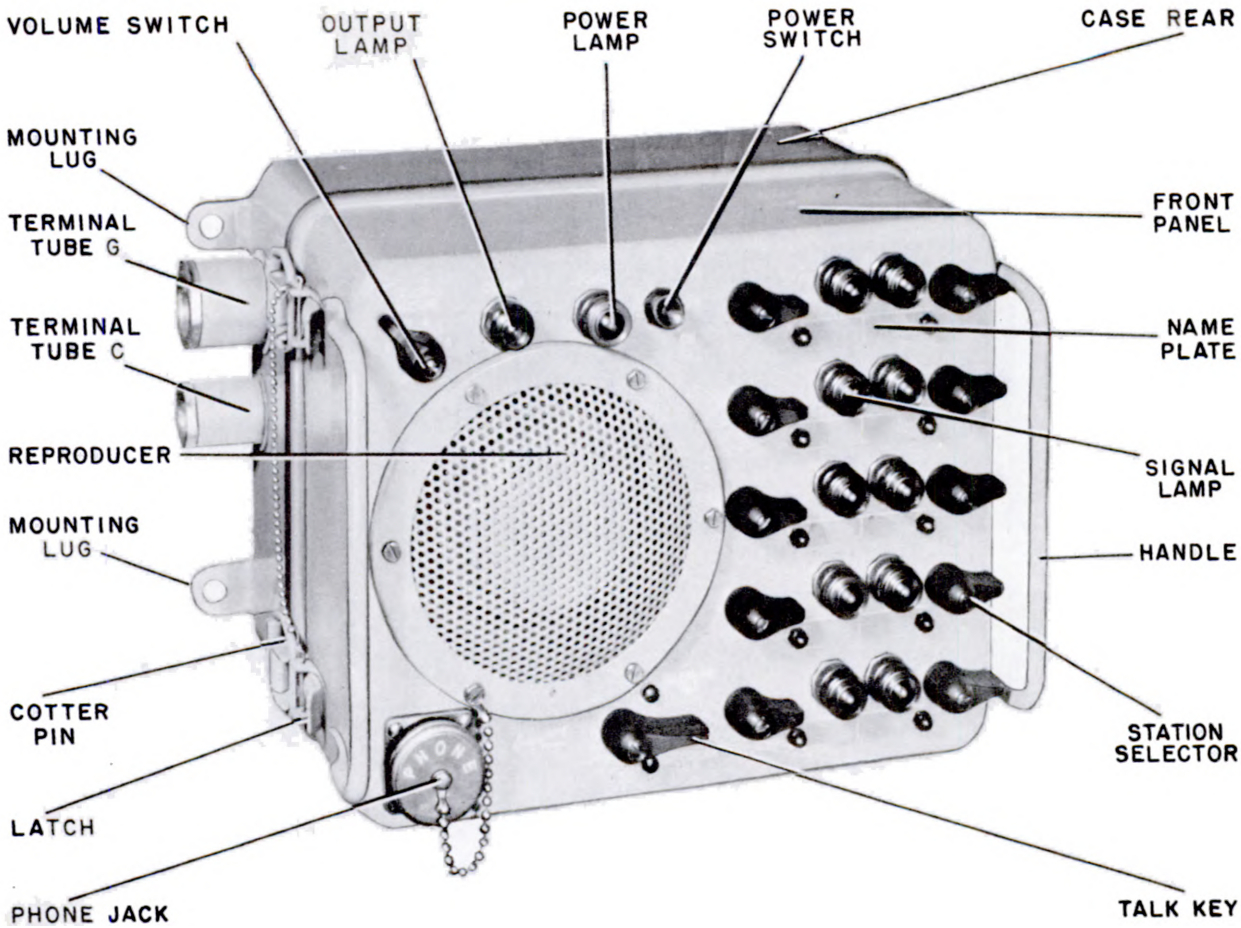

Figure 12-1.—Typical MC unit.

and all topside areas—wherever ship personnel are located. The 1MC also provides a means for transmission of general alarm and chemical attack alarm signals to the same areas.

Combat Information Announcing System, 20MC

The 20MC may resemble the one illustrated in figure 12-1, or it may be installed in a master console as shown in figure 12-2 The information passed over this system is mostly combat information from each main plotting group in CIC to primary and secondary conning stations, captain's tactical plot, open bridge, main battery control stations, air defense stations, main battery director stations, main and secondary battery plotting rooms, flag bridge, flag command and plotting stations, and RCM rooms.

Captain's Command Announcing System, 21MC

The 21MC is often called the "squawk box." This system provides for two-way transmission of ship control orders and information among key stations such as primary and secondary conning stations, signal bridge, main battery control stations, air defense stations, main communication station, damage control station, main engine control, CIC, primary fly control station, and captain's tactical plot. CIC uses the 21MC for sending initial contact reports or other emergency information to bridge. At times the signal bridge will transmit information received by flaghoist to bridge and CIC at the same time on the 21MC.

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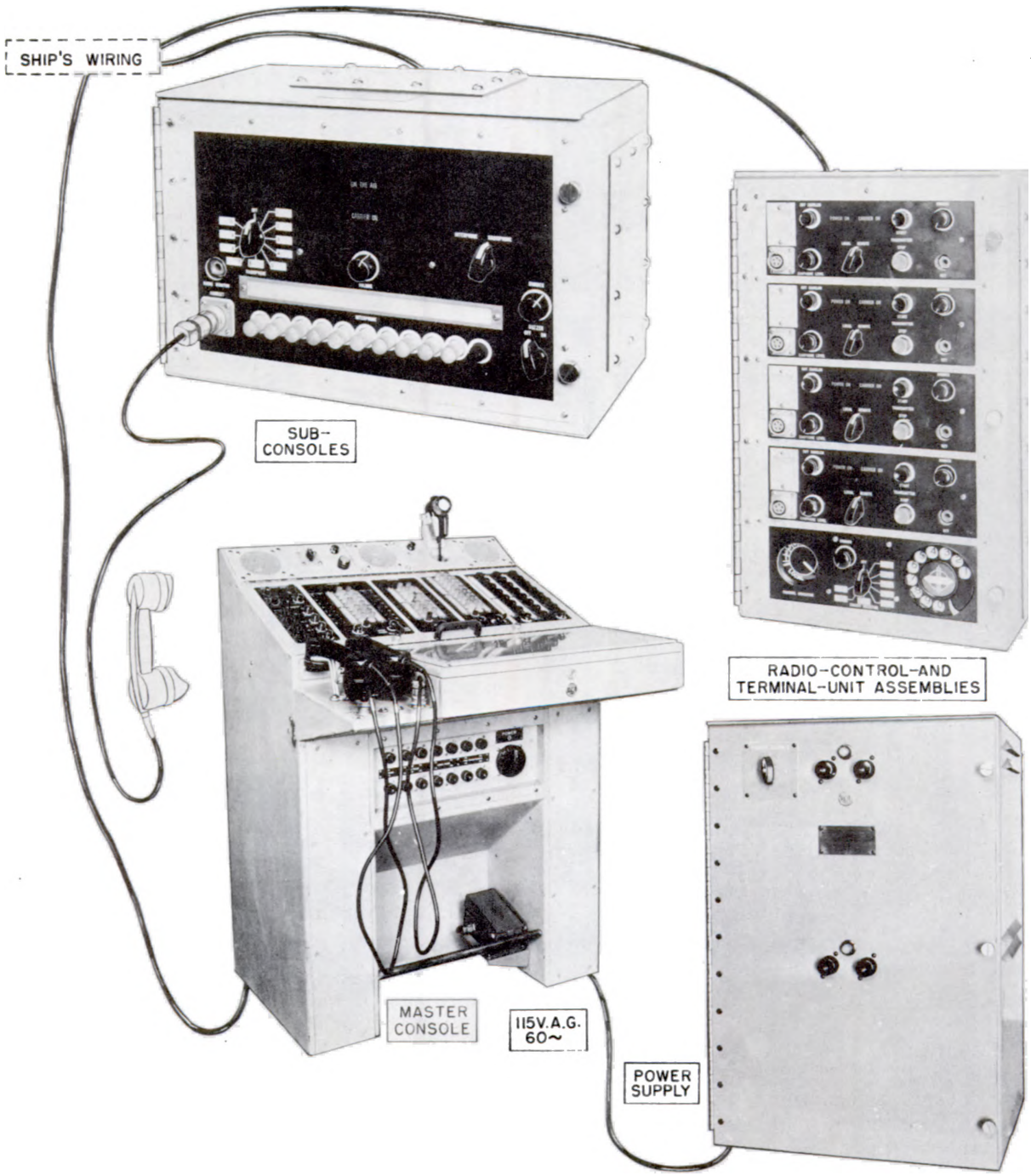

Figure 12-2.—Communication console equipment components.

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Radio Room Announcing System, 22MC

The 22MC looks exactly like the 21 or 20MC units except the station selector switches are marked with different stations. The system is used to pass information and orders concerning radio control orders and information between radio rooms and certain other radio operating stations. In CIC you may use it to call Radio to tell them to set up a frequency on a transmitter, or to check a radio receiver that may be drifting out of tune.

Flag Officer's Command Announcing System, 24MC

This system provides for two-way transmission of flag orders and information between such stations as flag bridge, signal bridge, flag plot, flag radio, main communication station, open bridge, combat information center, and captain's tactical plot.

Sonar Control Announcing System, 27MC

The 27MC is found aboard submarines and antisubmarine surface vessels equipped with special sonar equipment. This system allows the sonar operators' station to converse with CIC (or attack center) and conning station on submarines, and between sonar operators' stations and CIC, captain's tactical plot, open bridge, pilot house, underwater battery plot, and ASW attack station on surface vessels.

Sonar Information Announcing System, 29MC

This system provides direct, "hands free," one-way communication from sonar operators to captain's tactical plot, open bridge, pilot house, CIC, underwater battery plot, and ASW attack station. This system is only used on antisubmarine surface vessels.

COMMUNICATION CONSOLE EQUIPMENT

On some large types of ships a system like the one illustrated in figure 12-2, MASTER CONSOLE, type IC/JBB-1R may be found. Some ships have two or more of these. They provide a convenient grouping in one location for such personnel as evaluator or CIC watch officer, and for a large number of sound-powered telephone and radio circuits. Any or all of the radio and telephone circuits may be monitored at the same time either on a loud speaker or over a handset. It is possible to talk over any one of the circuits. The master console combines radiophone, interphone, intercom, sound-powered telephone, and the 20MC announcing circuit in one master console. A brief description of the system follows.

Radiophone

Each master console provides pushbutton selection of a combination of one to 16 radiotelephone circuits (channels or frequencies) for both transmitting and receiving.

Selector switches and volume controls mounted on the console provide facilities for the connection of amplifiers and overhead speakers to permit monitoring any four of 16 radiotelephone circuits.

A selector switch provides for the selection of any one of 16 radiotelephone circuits for quick relay playback, as recorded by a short-memory voice recorder.

Interphone

An interphone system provides two-way or network communications between master consoles and sub-consoles. Sixteen interphone circuits may be selected at the master console.

Intercom

Facilities are provided at each master console for communication with any combination, up to ten, of 20 ship's intercom stations.

Intercom systems differ from the interphone in this manner: Interphone systems use radiotelephone handsets or headphones, while the intercom systems are microphone speaker systems that provide amplified voice communications between two or more stations. They are used primarily during routine conditions when personnel are not available to man all the sound-powered telephone circuits. During general quarters and condition 1E, they should be used only for passing emergency information.

Soundphone

Each master console provides facilities for monitoring or two-way communications without cross-talk on any combination of 14 sound-powered telephone circuits. Provision is also

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made for crossing seven sound-powered telephone circuits, and for monitoring or transmitting on the crossed circuits. Cross-talk exists among the crossed circuits; if the 21 and 22JS circuits are crossed, for example, you will be able to hear both of them. At the same time the JA circuit may be used at the console without cross-talk. The sound-powered circuits can be monitored with either radio handset phones (not sound-powered telephone handset) or loudspeaker.

20MC Announcing System

A microphone mounted on the master console is provided for connection to the 20MC shipboard announcing system when the communication console equipment is installed in CIC.

Sub-Console

The sub-consoles provide secondary control points for radiotelephone and interphone circuits. They are usually mounted next to a radar repeater for use by air controllers. This makes a handy arrangement for the evaluator in CIC to signal the air controller and talk to him. Sub-consoles are sometimes installed in the RCM room and above the DRT.

1. Radiophone—Each sub-console may select any one of ten radio circuits for both transmitting and receiving. A radiotelephone jack (not sound-powered telephone) is provided for monitoring the selected radiotelephone circuit or interphone circuit.
2. Interphone—Two-way or network communication may take place from the sub-console to the master consoles and the other sub-consoles. Ten interphone circuits may be selected at the sub-consoles.

To further explain, take a look at the sub-console illustrated in figure 12-2. Notice the row of lights along the bottom. These are used for signaling. Suppose, for example, an air controller is using a radio headphone in conjunction with the sub-console to communicate with the CAP he is controlling. He is unaware that a bogey is closing the force. The evaluator sees the bogey displayed on the air summary plot and wants the air controller to use the CAP to intercept the raid. The evaluator would push the switch marked RADIOPHONE-INTERPHONE, located at the master console, to INTERPHONE. Then he would push the signal switch connected to that air controller to ON. One of the blue signal lights at the air controller's sub-console would light. Noticing this, the air controller would then push his RADIOPHONE-INTERPHONE switch to INTERPHONE and talk to the evaluator, still using the same headphone he used for controlling the CAP. After receiving the word from the evaluator to take the raid with his CAP, he would then push the RADIOPHONE-INTERPHONE switch back to RADIOPHONE and, by using radiotelephone start the interception. With this system, time is saved, and the evaluator needs no talker standing next to him to relay messages. The noise level is cut down because the evaluator need not talk very loudly.

Operation of the communication console equipment will not be discussed here. If you are required to stand a watch at this station while your ship is in port, you can find out how to operate it from the instruction book or from one of your leading petty officers.

Normally, the master console will be the CIC watch officer's station while the ship is underway. It provides a flexible communication system, combining control of radiotelephone, interphone, intercom, sound-powered telephone, and 20MC announcing circuits. He can conveniently monitor any circuit he desires. Also provided for his convenience is a horizontal desk surface of edge-lighted frosted plastic. This is covered by another sheet of clear plastic, and both are mounted in a hinged frame. Notes may be inserted between the two plastic sheets and can be read through the clear upper sheet. Or if he desires, he may write directly on the frosted surface of the lower sheet. A drawer is provided beneath the desk surface for pencils, paper, etc.

SOUND POWERED TELEPHONE EQUIPMENT

Now, let us consider the sound-powered telephone, the "work horse" of the shipboard internal communication system.

Figure 12-3 illustrates a sound-powered telephone chest set that Radarmen use in CIC, as plotters, talkers, or radar operators. The sound-powered telephone chest set consists of a microphone for transmission, earphones (headphones) for reception, a long portable lead for mobility, a jack plug (not shown in illustration) for connecting the set to a circuit by means of a circuit receptacle box, and accessories for

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suspending the set in front of the talker and holding the earphones securely over his ears.

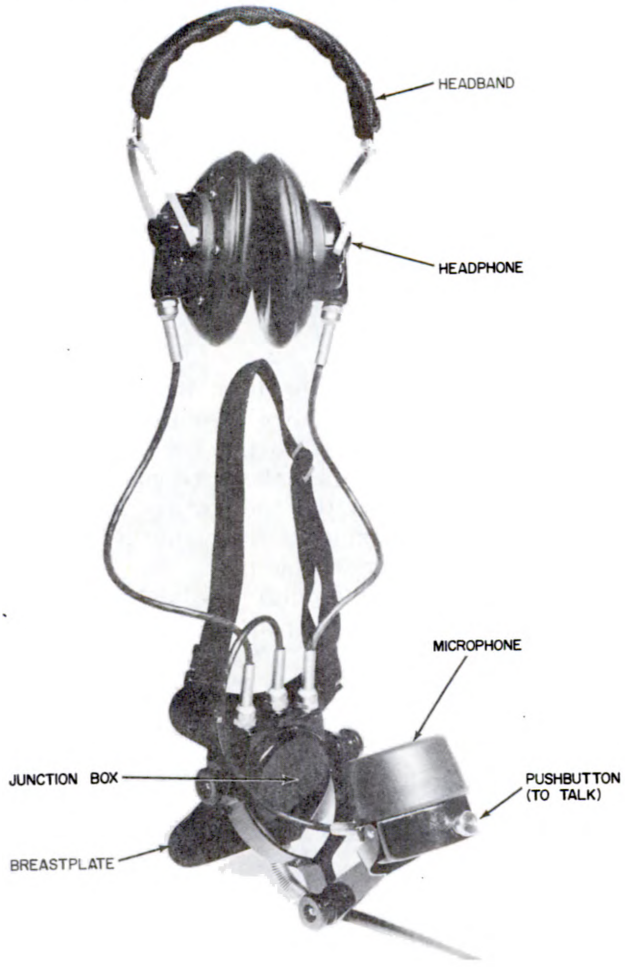

Figure 12-3.—Headset.

THEORY OF THE SOUND-POWERED PHONE

As the name implies, sound-powered telephones are powered with sound waves. When you speak into the mouthpiece (microphone), a thin metal diaphragm is caused to vibrate. The diaphragm is connected to a small coil of wire by a metal pin. As the diaphragm moves, the coil also moves back and forth in the field of a permanent magnet. The movement of the coil in the magnetic field causes an electric current to flow over the connecting wires, exactly duplicating in electricity the sound energy of your voice.

The electrical energy is fed to the receiver unit—a device similar to the transmitter—over transmission wires where sound is reproduced through vibration of another diaphragm.

A PARTY LINE

Many jokes have been told about persons who listen in on the party line home telephone for the purpose of finding out what the neighbors are doing. The 21JS and 22JS circuits are similar party lines; everyone on the lines can hear the conversation of the others.

Figure 12-4 is a diagram of a two-party JS system. Each unit is made up of a headpiece and a mouthpiece. Observe that each mouthpiece has a switch separating it from the main line. This switch is mounted on top of the mouthpiece.

When you wish to speak to some other party on the line, you press the button switch to connect the mouthpiece into the circuit. Hold the switch down while you are speaking. When you have completed the report, release the button.

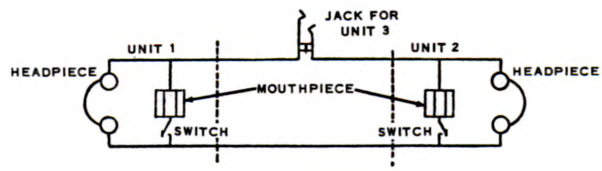

Figure 12-4.—Two-party telephone circuit.

PLUG-IN JACKS

Every sound-powered telephone circuit has several plug-in jacks so that others can break in on your party line. In figure 12-5 a single plug-in jack is shown.

The cutaway illustration of the jack and plug shows the type in use on most ships. This type in the illustration is called the male type; a later model is called the female type. The principles of both are the same. When the plug is inserted into the jack, point A of the plug makes contact with point A of the jack. At the same time part B of the plug connects with part B of the jack to complete the circuit. Parts A and B on the plug are separated by insulation as shown by the black line in the illustration. The insulator block shown separating parts A and B on the jack serves two purposes: to keep parts A and B separated thus preventing a shorted circuit, and to keep A and B at the correct distance apart so the plug will make a good connection when inserted.

The newer female type jack box and plug is similar in construction to the old type except that the plug is now located in the box

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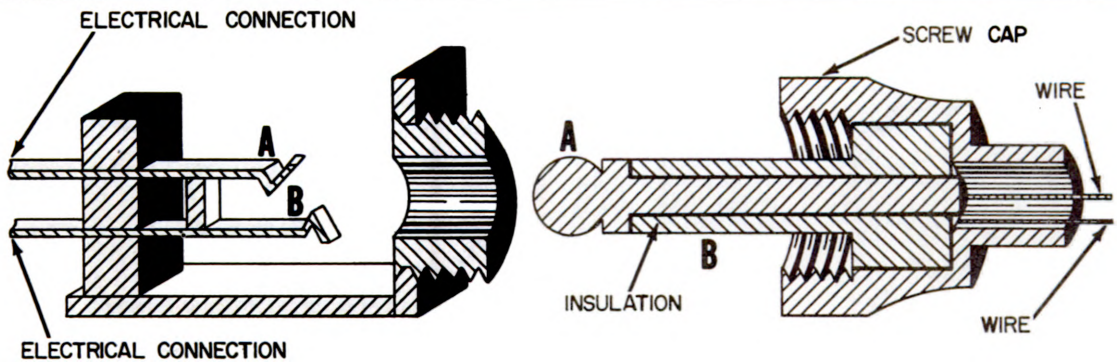

Figure 12-5.—Plug-in jack.

while the jack is attached to the telephone cord. This has been designed to eliminate the troubles caused by the failure of users of telephones to replace the old jack box screw cover. On the new design, by having the plug located in the box, rain, spray, and other foreign matter are not as likely to get into the interior of the box if the user forgets to replace the jack box cover. Foreign matter will cause grounds and other troubles if permitted to enter the interior of the box. Make it a point to replace the jack box cover after use. Also, if you see a box uncovered, put the cover on even if you are not responsible for this carelessness.

Two types of sound-powered outlets are generally used in CIC: the multiple circuit jack box and the drum type selector switch.

The multiple circuit jack box is similar to the single jack-box shown in figure 12-6, except that it has several toggle switches mounted on a panel next to the jack outlet. Each toggle switch is labeled, and by throwing the correct switch the jack box may be connected to any one of the circuits on the line. It is also possible to cross two or more circuits by throwing the proper switches to the ON position. If you use this type of box make sure you have all switches OFF except the one you are supposed to use. If any crossing of the circuits is to be done, the supervisor will do it.

The drum-type selector switch makes it possible to cut a single jack into any one of a number of circuits by turning the switch to the circuit marked on the face of the dial. Due to its construction, only one circuit can be connected at a time and two circuits cannot be crossed.

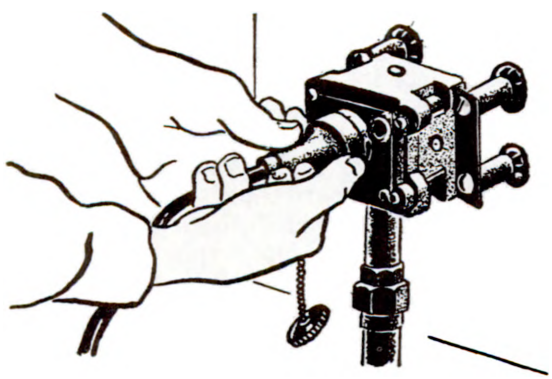

Figure 12-6.—Use both hands to release the plug.

OPERATION OF THE HEADSET

The operation of sound-powered telephone equipment is relatively simple. A normal sequence of operations would be as follows:

1. Remove headset from stowage box or stowage hook. When you pick up the set before putting it on, hold the entire set carefully in your left hand. You will find the headpiece is hung over the transmitter's supporting brackets and that the lead cord is coiled.
2. To put the headset on, you must first unhook the right side of the neck strap from the chest plate, unwind the neck strap from around the coil of wire and headband, put the strap around your neck, and then fasten it to the chest plate again.
3. Put on the earphones. Adjust the headgear so that the centers of the earphones are directly over the openings of your ears. You may have the job of relaying messages and want to keep one ear open for hearing what to relay. In this case be sure to have the earpiece not in use

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flat against your face or head. Remember any noises in the area will be transmitted to the other stations on the line if this precaution is not taken. Proper acoustic seal between the ear and the earphone cushion is necessary to exclude extraneous noises.

4. Straighten out kinks in the connecting cords.
5. Test headset for satisfactory operation by talking into the transmitter with the line switch depressed. The resulting sound will be heard in the receivers if the headset is not defective. Blowing into MC's and S/P phones is a bad practice (although a common one). The main reason is that it introduces rust-promoting moisture into the mouthpiece.
6. Insert the plug in its jack box. To find what jack box you should plug into, ask your leading petty officer. Upon reporting aboard ship you will be assigned a station where you will stand watches during normal steaming, a general quarters station, special sea detail station, man overboard station, etc.
7. Adjust transmitter to correct distance from the mouth. The mouthpiece should be adjusted so that it is directly in front of your mouth when you stand erect. When you speak into the mouthpiece, it should be about one-half inch and never more than 1 inch from your mouth. In making this adjustment remember that the fine wire that goes to the mouthpiece can easily be broken. Be sure that there are no sharp bends in it, and do not allow it to get caught between the transmitter and mounting brackets.

   An I. C. Electrician on almost any ship will tell you that he has several phones to repair every day just because talkers are careless in handling the phones. After you put the phones on, remember that you can't walk any farther than the length of the lead cord. If you do, you may break the connection at the jack plug or at the junction box. Therefore, always keep some slack in the lead cord, and be sure it is flat on deck so that no one will trip over it. Do not allow objects to roll over the lead.
8. Check into the net. As soon as the phones are manned (assuming this is a CIC circuit) CIC station control must know when all stations are ready. To do this, the talker at combat says—"All stations, combat, testing." Each talker on the line then acknowledges in order. On a radar circuit acknowledgments should sound like this—

   Talker on the AN/SPS-12 radar:
   "SPS-12, AYE, AYE."
   Talker on the AN/SPS-8 radar:
   "SPS-8, AYE, AYE."

   A circuit test is not complete until every man on the line has answered. In the case above the air plotters and status board keepers would also answer and report any faults in equipment.

If you are just checking into the circuit that is already manned the procedure is slightly different. For example, your ship receives word to assume the long-range air-search guard. The supervisor tells you to man the AN/SPS-12. This gear has been secured for some time. Upon getting the AN/SPS-12 on and tuned you would then establish communications with CIC. After donning the phones, your transmission would be "Combat, SPS-12, manned and ready." Combat would answer with "Combat, AYE, AYE."

TALKING INTO THE HEADSET

When talking into the transmitter, the lips should almost touch the mouthpiece and the press-to-talk switch on the top of the transmitter case must be firmly pressed down.

LISTENING

When listening, the switch should be released, thus eliminating the pick-up of extraneous sounds and also the loss in receiver signal strength due to the low impedance transmitter shunted across the line.

HOW TO TALK

Speak in a loud, clear voice. The power of the transmitter is generated by your voice, and the louder you speak, the louder the message is heard in the distant headsets. Shouting is not necessary.

DETECTING TROUBLE

When the headset transmitter is in use, the speaker hears his own voice loudly in his own receivers if the switch is closed. The loudness will decrease if the number of other headsets

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connected to this line is increased. If the line is short-circuited, there will be no response in the headset. Likewise, when a transmitter unit or a receiver unit is defective, there will be no response in the receiver when the line switch is closed. Where failure of either type is indicated, it should be reported promptly to the proper maintenance personnel and replaced if necessary.

EARPHONES WILL TRANSMIT AS WELL AS RECEIVE

In event that a sound-powered telephone headset transmitter becomes defective under conditions that prevent repairing or replacing it at once, communication can still be maintained. Remove one of the earphones from the headband and use it as a transmitter by speaking into it. Since headset receivers are connected in parallel, either can be used as a transmitter.

SECURING THE HEADSET

When station control grants permission to secure a circuit, observe the following in securing a telephone headset:

1. Hold plug with one hand and with other hand unscrew collar from jack box. This prevents twisting the wires and either breaking or weakening them. The plug should be removed from its jack box by pulling on the plug and not on the cord. Figure 12-6 illustrates the proper method.
2. Lay plug on deck.
3. Screw cover on jack box. Always do this immediately.
4. Remove headband and hang it on the transmitter yoke (fig. 12-7).
5. Coil the lead cord. Start coiling from the end at the phone, and leave the rest of the cord on the deck. Coil the lead in a clockwise direction, holding the loops in one hand. This is necessary to standardize the making up of all phones. The loops should be 8 to 10 inches across, as shown in figure 12-8, depending on the size of the space where the phones are to be stowed. When you are coiling the lead, be careful not to bang the plug against the bulkhead or deck.
6. When the lead is coiled, remove the earphones from the transmitter yoke and put the headband in the same hand with the coil.
7. Unhook neck strap. While unhooking the strap hold the transmitter with the same hand that the coil of wire is in to hold the transmitter and chest plate firmly. With the other hand unhook one end of the neck strap from the chest plate. Figure 12-9 shows how this is done.

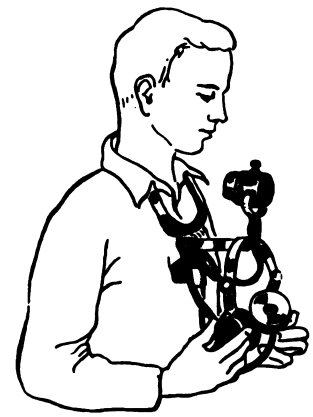

Figure 12-7.—Hang headpiece on mouthpiece yoke.

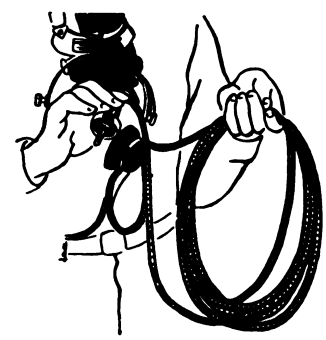

Figure 12-8.—Coil lead carefully.

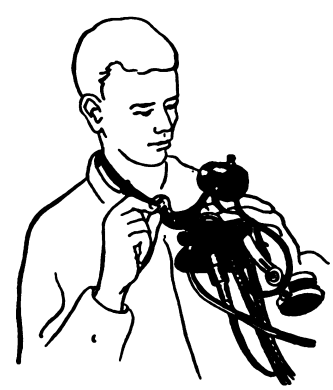

Figure 12-9.—Unhook strap from breast plate.

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8. Straighten out any sharp bends or kinks in the connecting cords.
9. Wind neck strap around coil and headband and fasten. As shown in figure 12-10, the back of the chest plate is brought together with the headband and the coil. They are secured in this position by winding the neck strap around the coil and the headband. Wind just enough times so that there is a short end left over. Fasten this end back on the breast plate. Be sure to wind the neck strap around both the main lead and headband. You then have a neat, compact package (fig. 12-10), ready to be stowed.
10. Place headset in stowage box or on stowage hooks. No part of the headset or cords should protrude from its stowage box. The stowage box should be tightly closed. Figure 12-11 shows one type of phone stowage box. This type is found mostly on topside spaces. Most CIC's use hooks to hang the phones by the coil.
11. The headset should never be allowed to lie on the deck and should never be hung on equipment when the station is secured unless the ship is in a war zone and a general alarm may be sounded at any time.

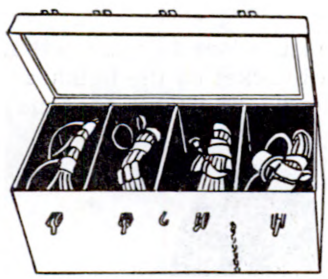

Figure 12-10.—Wrap neck band about coil.

CARE OF TELEPHONES

Sound powered telephones are of very sturdy construction, and if handled with reasonable care should require little attention. Nevertheless, they are fine instruments performing an important function and should be treated accordingly.

1. Avoid pulling on the electrical connections, and never use the cables for carrying or handling the equipment.

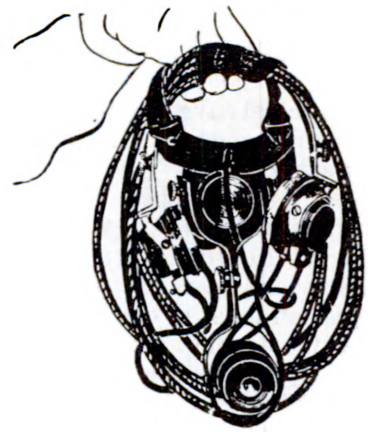

Figure 12-11.—Secure in proper place.

2. Remember that the cord is only so long. If you attempt to walk any farther than cord permits, it will pull out of the jack easily.
3. Unauthorized persons should not remove the units from their housings nor tamper with them in any way.
4. Do not insert any object through a protective screen. The diaphragm may thereby be damaged.
5. When secured and telephones are made up, stow on hooks or in stowage box provided. Never leave the telephones adrift or exposed to the weather.
6. Never take a pair of telephones from a a stowage box that does not belong to your station. General quarters may be sounded. The man normally using those phones may be a key person, and the fate of the ship may hinge on his being able to man his phones immediately.
7. When wearing a pair of phones, always try to keep the excess cord out of the way of people passing by. If the cord is left in the way, a person may trip on it and cause injury or damage.
8. Telephones that are out of order should be tagged and turned in at once to the I. C. room or telephone repair locker. Do not leave inoperative telephones on station.

A GOOD TALKER

To be a good telephone talker a man must have at least three characteristics. First, he must be able to speak well (clearly, loudly),

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and at the proper rate of speed. Second, he must be able to listen well—to receive commands even when there are loud noises near his station. Third, he must have the ability to remember a series of words and numbers so that they can be repeated exactly.

Good speech for telephone talkers is simple and straightforward speech. It has little to do with the "arty" or "fancy." Speech is a highly modifiable process; that is, it can be changed more easily than most of our daily habits. This becomes obvious when you think of how you change your speech when you talk to a deaf person, to a child, or to a foreigner. To the deaf person you speak much more loudly, to the child more simply, and to the foreigner more simply, more slowly, and perhaps more loudly. A good talker is one who makes the necessary vocal changes for intelligible speech and who maintains intelligible speech while talking on the phone.

SOUND-POWERED CIRCUITS

The separate sound-powered telephone circuits are divided into three general systems on board ship: the primary and auxiliary systems in the battle telephone network, and the supplementary system.

Primary System

Actual installations will vary with size and type of ship, but on larger ships, the primary battle telephone system is connected to a switchboard in the interior communication (IC) room. At the switchboard, it is possible to cross-connect any or all circuits on that switchboard, or disconnect separate defective circuits (or stations). In individual circuits there will be an action cutout box to eliminate faulty stations.

Auxiliary System

Some of the most important battle stations are linked by more than one telephone circuit. For instance, a circuit called the XJA parallels the JA circuit. The "X" in the designation indicates it is an auxiliary system. In case a primary circuit becomes damaged in battle or is otherwise rendered inoperative, the stations shift to the auxiliary system. It is possible to cross-connect separate circuits in the auxiliary system and to disconnect selected stations within a circuit. Here again, the actual installation will vary with the size and type of ship. It is also useful to know that as a rule, the wiring cables for the primary system are installed on one side of the ship and the auxiliary system on the other. This is a precaution against both systems being damaged in battle by the same explosion.

Supplementary System

The supplementary system is not a part of the general battle telephone system. This means that it is not normally manned during general quarters. It is, however, available for use. The system consists of several short, separate circuits (such as from the bridge to the captain's sea cabin; the bridge to the signal bridge, the communication office, the in-port quarter deck, etc.). Instead of chest sets, permanent handsets are installed at the various stations (fig. 12-12), and an E-call or buzzer system enables a station to call another station to man the phone. The normal use of the supplementary system is for routine internal communications.

You can see from figure 12-12 that the handset telephone looks very much like the cradle or French-type telephone used in many offices and homes. It is held in one hand. When the earpiece is placed against the ear, the transmitter or mouthpiece is directly in front of the mouth. There is a pushbutton on the bar connecting the receiver and the transmitter. This button must be held down whenever you are speaking or listening.

When the handset telephone is not in use, it is held in a bracket on the bulkhead. There is a clamp in this bracket that keeps the phone firmly

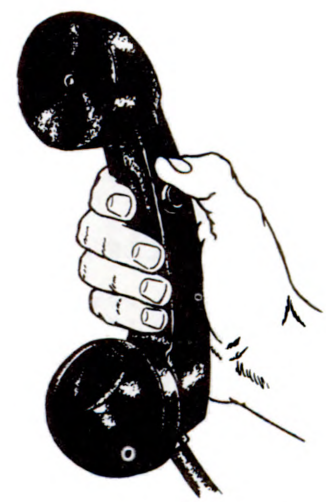

Figure 12-12.—Handset.

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in place. Be sure that the phone is secured in this clamp when you are through using it. Otherwise, it might fall out of the bracket and on to the deck, which could result in serious damage.

The handset phone, although convenient, has definite disadvantages. For example, it is not suitable for standing a continuous circuit watch. Usually it is employed (under battle conditions) in emergencies, when there is a headset phone failure, or when the headset is not manned at the station you wish to call.

CIRCUIT NOMENCLATURE

Each separate sound-powered telephone circuit is for the specific purpose of providing communications. The groups linked by a sound-powered circuit may include the gun batteries, the underway and docking stations, and the damage control teams. Identification of the separate circuits is by their employment. A letter and number code is used.

J--The first letter of primary and powered circuit designation is J. It indicates that it is a sound-powered communication link.

JS--The second letter identifies the general purpose of the circuit. The letter S means that the circuit is used for radar information.

21JS--Numerals preceding the letters indicate the specific purpose of the circuit. In this example, the designation means that it is an air-search radar information circuit.

21JS1--Numerals following the letters indicate a particular station in the circuit. For example, the air summary plotter.

X21JS1--The letter X indicates that the circuit is in the auxiliary battle telephone system.

CIRCUIT REQUIREMENTS IN CIC

The number of sound-powered telephone circuits required in CIC varies with the type of ship. As a general rule, there are more circuits in larger ships than in smaller ones. There are, however, certain minimum circuit requirements in all types. These are:

1. A separate circuit between each search radar to CIC.
2. A separate circuit between the RCM room to CIC and other stations.
3. A separate circuit between the visual lookout stations to CIC and to other stations.
4. A separate circuit linking radio central (communications) to CIC and other stations.
5. A separate circuit between CIC, the bridge, and other conning stations.
6. A separate circuit from (on flagship) providing direct communications between CIC and flag plot.
7. A separate circuit between CIC and each gunnery control station, including sonar in sonar-equipped ships.
8. A separate circuit for aircraft information in carriers.

Large ships, on which there are a great many more sound-powered telephone circuits, use a more elaborate phone setup. This is to accommodate the larger CICs. The number of phones manned depends on what the ship is doing. More circuits are manned during general quarters than during a normal condition watch.

It will help you to know the phone setup for your ship's CIC doctrine and the watch, quarter, and station bill. You should also make it a point to learn what information is carried over each circuit. A few of the more common circuits are listed below.

JA--Captain's command
1JC--Turret control
JF--Flag
JL--Lookouts
81JS--Radar radio countermeasures
1JV--Maneuvering and docking control
1JS--Radar information
21JS--Search radar No. 1
22JS--Search radar No.2
23JS--Search radar No. 3
JU--Torpedo and depth charge control

ADVANTAGES OF SOUND-POWERED TELEPHONES

There are several advantages of sound-powered telephone equipment for internal communications. A few of them are:

1. Operation is simple.
2. The equipment is rugged, given reasonable care.
3. Talker is not distracted by external noise since his ears are muffled by the ear pads.
4. Security or privacy of communications as compared with MC equipment.
5. Transmissions do not contribute to station noise levels.
6. The talker is mobile within the limitations set by the length of the cord.

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7. The talker is free to perform other tasks with his hands, as in the case of the radar operator or the plotter in CIC.
8. The earphones may be used for emergency transmissions in case the microphone should be defective.
9. The system does not require an external source of power and is sufficiently flexible to ensure maximum probability that communications will not be disrupted during battle.

TARGET DESIGNATING EQUIPMENT

Inasmuch as CIC is the principal agent for the collection of combat information, many ships have target designating equipment installed. This equipment allows CIC to provide a signal to the gun control stations which will assist in the acquisition of targets. In some ships the radar target designation equipment is not located in CIC, but is a separate station; however, its operation is closely integrated with CIC. The target designating equipment is normally operated by gunnery department personnel as directed by the gunnery officer. Briefly, target designation equipment is a rapid, silent, and very effective means of communicating combat information.

VOICE TUBES

Voice tubes provide another important means of internal communications. This system is nothing more than a network of metal tubes designed to carry the sound of the voice from one station to another. Its major value lies in the fact that it is practically immune to mechanical failure. It can, therefore, be relied upon when casualties disrupt other systems. Voice tubes are only used as a standby means of communication.

SHIP'S SERVICE TELEPHONES

Although the ship's service phones are not part of the battle communication system, they have proven invaluable when the regular systems have failed. They are standard telephones powered by the ship's generators and intended for use in carrying out normal routine on large ships.

MESSENGERS

Ships still use the oldest method of communication, the messenger. Messengers are a reliable means of sending a message but they are not as fast as the methods we have discussed. Many times during your naval career you'll be called on to use your knowledge of the ship by acting as a messenger.

Teletypewriter, pneumatic tubes, and even the walkie-talkie have been used on large ships. Closed-circuit television may be used also. Even so, the sound-powered phone system, a long way from being displaced, will continue to be the basis of a smooth-working interior communication system.

SUMMARY

Internal communication systems are tools which assist Radarmen to function as a team. As a Radarman you must be thoroughly familiar with the means of communication to disseminate and receive information. To do this, you must know when communication systems are operating properly and when they are defective. You must know how communication equipment must be handled and kept from being abused. Knowing what can be done with the equipment, you must learn its use in providing communications with reliability, security, and speed. These qualities are achieved only by using the proper circuits to pass information to all stations which need the information, and by passing information in clear, acceptable form. The latter is achieved by using standard sound-powered telephone procedure and phraseology. Standard sound-powered telephone procedure and phraseology will be our next subject for discussion.

STANDARD SOUND POWERED TELEPHONE PROCEDURE AND PHRASEOLOGY

Since there may be a great number of possible personnel manning a sound-powered circuit, standardized procedures must be maintained for most efficient use of facilities. These are listed in this section.

USE OF SOUND-POWERED PHONES

When wearing sound-powered telephones the following points must be observed at all times.

1. Test equipment as directed by the circuit controller.
2. Adjust transmitter so that it is one-half inch from mouth and center the earpieces over ears.
3. Shield microphone when transmitting in a high wind.

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4. Talk in a loud, clear voice at all times.
5. Speak slowly and remain calm.
6. Repeat information exactly as received.
7. Hold transmitter button down only when speaking, unless authorized to tape it down during special work requiring both hands.
8. Use phonetic alphabet and correct numeral pronunciation.
9. Make no unauthorized transmissions.
10. Circuit discipline is self-discipline; keep calm and use correct procedure.
11. Call station to be contacted; identify own station; send message. Example: BRIDGE (call); COMBAT (identify); MANNED AND READY (send message).
12. Acknowledge all messages when they are understood. For above message, acknowledgment would be: BRIDGE AYE, AYE. If not understood, say only SAY AGAIN.
13. If transmitter should go dead, get another set, or in an emergency talk through earpiece.
14. Report faulty equipment at once. Leave repairs to responsible personnel.
15. Leave telephones only when authorized to do so.
16. In securing, coil lead wire carefully so that it is not kinked, fold telephone, and hang or stow carefully in box provided. Secure jackbox by firmly screwing on watertight cover.

STANDARD SOUND POWERED TELEPHONE PROCEDURE

The purpose of standard sound-powered telephone procedure is to provide uniformity of expression. In every CIC in the fleet, day in and day out, Radarmen deal with the same type of information, over and over—bearings, ranges, speeds, distances, and other tactical data. If CIC personnel have a simple, easily understood and readily used system which permits every transmission to be placed in brief and clear form, a form which is understood instantly and is ready for use when received, they will be able to handle information with speed, accuracy, and reliability. There is such a system: Standard sound-powered telephone procedure and phraseology. The system is simple. To be a Radarman you must learn to think and speak in its terms. Remember this: speed is not achieved by transmitting rapidly and biting off words or running them together; you gain speed by using standard procedure with every transmission.

BASIC MESSAGE FORM

The basic form for transmitting a message by sound-powered telephone consists of the standard shipboard names for the station called and the station calling, followed by the text (what is to be said) in clear, concise language. Example:

Station Called: Bridge—
Station Calling: Combat—
Text: Surface Contact—Two Six Zero—
Twenty Thousand—May be Submarine.
Response: Bridge—Aye, Aye.

NOTE: CIC personnel do not call a station and wait for the word to go ahead. In every case, when you have information to transmit, call the station or stations concerned, identify your station, and send the message. If you do not get a response, repeat your message.

PROCEDURE WORDS AND PHRASES

If every transmission was received by all stations on the first transmission and entirely understood, there would be no need for anything more than the procedure just covered. Unfortunately, transmissions are not always received perfectly. Errors are made while transmitting; communication is difficult at times. Prowords provide a further standardization of sound-powered telephone language. The use of them will help.

AYE, AYE.—Aye, Aye means: "I have received all of your last transmission." It is the standard response to all transmissions which are completely received. It informs the transmitting operator that his message has been received and necessary action will be taken. Never use this response if you are not sure that you have received all of the transmission. When you receive a message, take immediate action in every case. Use the information if a job requires it, or pass the information at once to the person who is required to take action.

CORRECTION.—The procedure word "Correction," preceded and followed by a pause during a transmission indicates that an error has been made and it is being corrected. Its use might be prompted by a mispronounced word, deletion of a word or phrase in the text, or upon the transmission of wrong information. The correction to the message is made clearly to

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eliminate misunderstanding. When it is seen that an error has been made, pause, speak the word CORRECTION, pause, then go back to the last word or beginning of the last phrase transmitted correctly. Re-transmit it, and resume the message. This procedure is particularly important when transmitting a series of numerals.

SAY AGAIN; I SAY AGAIN.—The procedure word "Say Again" means: Repeat all of your last transmission. When followed by identification data it means Repeat___(portion indicated). The procedure word "I Say Again" means: I am repeating the transmission or portion indicated.

THAT IS CORRECT; WRONG.—The proper reply to a question or a portion of something that has been transmitted is: "That Is Correct" if the questioned version was correct; or: "Wrong" followed by the correct version if the questioned version were wrong.

DISREGARD THIS TRANSMISSION.—In some cases, while transmitting a message and before completing it, it is found that an error has been made which can be corrected clearly only by stating it over; or it may be found that, for some reason, the message should not be transmitted. In such cases use the phrase "Disregard This Transmission." Do not use this phrase to cancel a message which has already been transmitted completely and received.

WAIT.—The procedure word "Wait" is used to indicate a pause of short duration—several seconds—during a transmission. It can also be used when information not immediately available is requested.

OPERATIONAL BREVITY CODES

The operational brevity codes are word and phrase vocabularies for use on radiotelephone nets and sound-powered telephone circuits manned by CIC and other personnel familiar with them. They provide brevity and clarity to communications, a basic knowledge requirement for Radarmen.

ACP 165 is the basic operational brevity code book. It should be used exactly as prescribed—that is, according to the strict meaning of each word and phrase. From time to time, other publications listing code words are promulgated. Code words not listed in ACP 165 or other authoritative service publications are not authorized for use.

Here's a list of commonly used code words.

ALTITUDE.—Altitude of aircraft, in feet.

BENT.—Equipment indicated inoperative or unserviceable.

BOGEY.—Unidentified aircraft. It implies that the aircraft should be investigated with caution for it may be friendly.

CEASE REPORTING.—Further reporting of information on the contact or raid designated is no longer to be supplied.

CHECK CONTACT.—Check the designated contact for identification purposes.

CLARA.—Radarscope is clear of contacts other than those known to be friendly.

CLOSING.—Range decreasing appreciably.

CLUTTER.—Contact has entered scope clutter.

CONFUSED.—Intensive activity; individual tracks not identifiable.

CONFIRM.—Verify existence of designated raid or track.

CONTACT.—I have an indication on my radar.

CONTACT LOST.—The indication on my radar has faded.

CROSSING.—Passing (from__to__) but not appreciably changing in range.

ESTIMATE.—Provide a quick estimate of the altitude and size of designated contact.

FADED.—Contact has disappeared from reporting station radar.

FEW.—Two to ten aircraft.

FRIENDLY.—Friendly aircraft or ship.

INTERFERENCE.—Plot or altitude not reliable due to interference.

INTERROGATE.—Interrogate the contact/raid indicated.

MANY.—Eleven or more aircraft.

MAYDAY.—Distress call.

MERGED.—Contacts/plots have come together.

MIX-UP.—Mixture of friendly and hostile aircraft.

NEGAT.—Cancel; cease.

OPENING.—Range increasing appreciably.

PARROT.—IFF Mark X.

RACKET.—Intercepted unidentified or enemy electronic emission.

REPORT.—Pass frequent reports on the contact/raid designated.

SCAN.—Search__to__and report any contact.

SCRUB.—Erase the contact/track/raid indicated from all plots.

SINGLE.—One object.

SKUNK.—Enemy or unidentified ship or surface craft.

SPLITTING.—Contact is dividing.

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SQUAWK (ING).—Show(ing) IFF Mark X.

SWEEP.—Keep all-around search and report any new contacts.

TOO NEAR.—Contact has entered scope clutter.

TRACK.—A series of related contacts displayed on a plotting board.

WATCH.—Continue to sweep as directed and concentrate on the contact/track/raid designated, but do not report unless there is a material change.

These are only a few of the code words listed in ACP 165. Remember that the primary purpose of the code is to provide a brief, clear, and standard procedure for transmission of orders and exchange of information on radiotelephone and sound powered telephone circuits.

NUMERALS

Although it is not possible to standardize completely the phraseology used in the text of a sound powered telephone message, numerals can be and are standardized. Inasmuch as numerals are the Radarman's "chief stock in trade" and because the accuracy of most of the information supplied by CIC is expressed in numerical form—bearings, ranges, speeds, distances, time, etc.—you should learn from the beginning to treat numerals with the care they deserve. CIC personnel cannot afford to make errors in the information that they handle since, in many cases, it is VITAL to ship control. Numerical errors concerning enemy forces passed on to the command might prove disastrous in wartime. In peacetime, numerical errors concerning tactical maneuvering or navigational data can also add up to disaster.

For example: say the following numbers aloud: 7, 11, 17, 70 (SEVEN, ELEVEN, SEVENTEEN, SEVENTY). Notice that the sounds are similar. If they are slurred, or pronounced indistinctly, there is room for error. A carelessly pronounced SEVENTEEN could conceivably be understood as SEVENTY. And if range (in miles) is the subject, an error of 53 miles is introduced. Let us see how such an error can be avoided. You will find as you gain experience that there are a number of communication procedure rules designed to eliminate errors. You will also see that there is a good reason for every rule.

Basic Digits

There are ten basic digits in the numerical system. Each digit must be pronounced distinctly so that it will be understood clearly. Learn to pronounce them as written here:

0 ZERO	5 FI-YIV
1 WUN	6 SIX
2 TOO	7 SEVEN
3 THUH-REE	8 ATE
4 FO-WER	9 NINER

Rules For Pronouncing Numerals

If all to be considered in use of numerals were the ten basic digits, there would be little problem. Unfortunately, numerals may form an indefinite number of combinations and the combinations may be spoken in a number of different ways. Following this paragraph are rules which apply to the pronunciation and expression of numerals. Situations may arise, however, in which these rules are not applicable. In such cases pronunciation and expression will then be used to best fit the situation.

1. The numeral 0 (written Ø) shall always be spoken as ZERO and never as OH. This applies to ranges as well as to bearings.
2. Decimal points will be spoken as POINT.
3. For ranges and distances given in units other than miles, numbers will be transmitted digit by digit except that exact multiples of hundreds and thousands will be spoken as such:

Number	Spoken as
44	FO-WER FO-WER
90	NINER ZERO
136	WUN THUH-REE SIX
500	FI-YIV HUN-DRED
1400	WUN FO-WER HUN-DRED
1478	WUN FO-WER SEVEN ATE
7000	SEVEN THOW-ZAND
16000	WUN SIX THOW-ZAND
20000	TOO ZERO THOW-ZAND
16500	WUN SIX FI-YIV HUN-DRED
812681	ATE WUN TOO SIX ATE WUN

4. Ranges, distances, and speed given in mile units will be transmitted as the integral cardinal number:

Number	Spoken as
10	TEN
13	THUR-TEEN
25	TWEN-TY FI-YIV
50	FIF-TY
110	WUN HUN-DRED TEN
300	THUH-REE HUN-DRED

5. Altitude is always expressed in feet except for gunnery orders and information

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concerning gunfire support, and may be spoken either in exact integral cardinal numbers or in multiples and tenths of thousands using the integral cardinal numbers:

Number	Spoken as
700	SEVEN HUN-DRED or POINT SEVEN
1100	ELEVEN HUN-DRED or WUN POINT WUN
5500	FIF-TY FI-YIV HUN-DRED or FI-YIV POINT FI-YIV
10500	TEN THOW-ZAND FI-YIV HUN-DRED or TEN POINT FI-YIV
20000	TWEN-TY THOW-ZAND or TWEN-TY

NOTE.—The foregoing differences are readily seen in the case of aircraft control situations where friendly aircraft altitude or "angels" is given in exact numbers.

6. Altitude and other information concerning gunfire support is always expressed in yards and will be transmitted digit by digit except that exact multiples of hundred and thousands will be spoken as such:

Number	Spoken as
10	WUN ZERO
25	TOO FI-YIV
50	FI-YIV ZERO
100	WUN HUN-DRED
1000	WUN THOW-ZAND

7. Bearings and angles except for position angles will be given in three digits and will be transmitted digit by digit:

Number	Spoken as
090	ZERO NINER ZERO
180	WUN ATE ZERO
295	TOO NINER FI-YIV

8. Position angles, being always less than 90°, may be expressed in one or two digits, and will be pronounced as the integral cardinal number. When so transmitted, the phrase "position angle" shall always precede the numerals:

Number	Spoken as
5	POSITION ANGLE FI-YIV
10	POSITION ANGLE TEN
15	POSITION ANGLE FIF-TEEN
27	POSITION ANGLE TWEN-TY SEVEN

9. Raid reporting. In referring to raids, and in raid reporting, the raids will be transmitted as the integral cardinal numbers:

Number	Spoken as
3	THUH-REE
10	TEN
13	THUR-TEEN
24	TWEN-TY FO-WER

Other Uses of Numerals for CIC

Let us consider other important uses of numerals in CIC. Memorize these additional uses and learn how to pronounce numerals in the proper standardized form in each particular case.

Courses:	290 — TWO NINER ZERO — always three digits and spoken digit by digit.
Time:	1215 — ONE TWO ONE FIVE — always digit by digit, and preceded by the word TIME.
Lat. and Long:	147° 28' — ONE FOUR SEVEN TWO EIGHT — alwavs digit by digit.
Grid coordinates:	MK 2645 — MIKE KILO TWO SIX FOUR FIVE — always digit by digit for numerals; phonetic alphabet pronunciation for letters.
Aircraft speed:	340 — THREE HUNDRED FORTY — integral cardinal number.
Ship speed:	21 — TWO ONE — digit by digit.
Quantity:	30 to 40 Planes — THIRTY TO FORTY PLANES — integral cardinal number. 10 Ships — TEN SHIPS — integral cardinal number.

Phonetic Alphabet

There is also a standard pronunciation procedure for initials (letters), helpful in the spelling of difficult words. This is called the phonetic alphabet.

Letter	Phonetic Equivalent	Spoken as
A	ALFA	AL-FA
B	BRAVO	BRAH VOH
C	CHARLIE	CHAR LEE
D	DELTA	DELL TAH
E	ECHO	ECK OH
F	FOXTROT	FOKS TROT
G	GOLF	GOLF
H	HOTEL	HOH TELL
I	INDIA	IN DEE AH
J	JULIETT	JEW LEE ETT
K	KILO	KEY LOH
L	LIMA	LEE MAH
M	MIKE	MIKE
N	NOVEMBER	NO VEM BER
O	OSCAR	OSS CAH
P	PAPA	PAH PAH
Q	QUEBEC	KEH BECK
R*	ROMEO	ROW ME OH
S	SIERRA	SEE AIR RAH
T	TANGO	TANG GO
U	UNIFORM	YOU NEE FORM
V	VICTOR	VIK TAH

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W	WHISKEY	WISS KEY
X	XRAY	ECKS RAY
Y	YANKEE	YANG KEY
Z	ZULU	ZOO LOO

*Note: ROGER will continue to be used as a proword; ROMEO will NOT be used as a proword.

When you have a confusing group to transmit, transmit the phonetic alphabet equivalent. Example: B201L; BRAVO TWO ZERO ONE LIMA.

When you transmit a difficult word (remember to avoid use of difficult words when possible), it may be necessary to spell it so that the other station will understand it. When you do, use the phonetic alphabet. Example: Kwajalein — I spell — KILO WHISKEY ALFA JULIETT ALFA LIMA ECHO INDIA NOVEMBER — Kwajalein.

CIRCUIT DISCIPLINE

The sound-powered telephone talker has a job of considerable responsibility. He not only must know how to transmit his information in a standard way, but he also must know how to conduct himself on the circuit. Here are a few important rules which must be observed at all times.

BE ALERT. — If your job is simply that of a talker, be nothing else. Transmit your messages exactly as they are given to you; pass them along exactly as they are received. Do not change them. If your job is that of a radar operator, a plotter, a status board keeper, and you use sound-powered telephones to enable you to perform your primary job, perform both jobs equally well. They are of equal importance.

TRANSMITTER BUTTONS. — Buttons on transmitters will be released when the telephones are not in use.

TALKERS ON DUTY. — Talkers will not leave assigned circuits without authorization.

BULL SESSIONS. — Unofficial conversation is forbidden. This means that you will transmit authorized transmissions only — those required to perform your primary job, or those you have been directed to transmit. You will not engage in personal conversation or excessive testing. Test your equipment when you first man a circuit to ensure that it is working properly. Then keep alert and quiet and listen.

SECURITY. — The information you handle is official information. It must be sent to all stations which need it to enable assigned personnel to perform their jobs — and to no one else. Do not discuss information you acquire on communication circuits with persons who are not concerned. This rule applies both on and off the job.

BREVITY. — Transmissions will be reduced to the least number of words that will merit effective communications.

STANDARD TERMINOLOGY. — Standard commands, phraseology, and nomenclature will be used habitually on the circuits.

TAKE IMMEDIATE ACTION. — If you receive information, use it immediately in performance of your primary job or pass it on immediately to those who need it. If you have information to transmit, transmit it without delay. Listen before transmitting. Do not break in on another transmission. If you have information that is more important (such as information that concerns the safety of the ship), break in on the line by saying "Silence on the Line," then transmit your message. If YOU should hear "Silence on the Line," stop talking immediately.

MICROPHONE TECHNIQUE

Speak slowly into the microphone with the lips one-half inch from the mouthpiece. When you have started to transmit, do not vary the position of the lips and the microphone. Pronounce each word distinctly, and speak in natural phrases. Adjust your overall speed so that the average person will be able to record your transmission with pencil and paper, if necessary. Transmit all messages deliberately so that all stations will receive them clearly on the first transmission. This is the key to SPEED. Rapid, indistinct transmissions will make repetitions necessary, cause errors, and slow down communications.

STANDARD TERMINOLOGY IN REPORTS

Standard terminology in reports may best be described by imagining we are listening in on a circuit connected from the bridge to combat. This circuit is chosen because it also shows how the proper reports will be made from the radar operator to CIC. The telephone talker in CIC must be well trained and thoroughly dependable. It is his job to keep the conning officer informed of the tactical situation with a minimum of direction from the CIC officer. He must be sufficiently familiar with all CIC procedures so that he may recognize information which should have immediate attention of the conning officer.

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And he must be able to transmit it without delay in proper form. This is a sample conversation between CIC and Bridge.

Bridge	Combat	Testing.
	Bridge	Aye, Aye.
Bridge	Combat	Manned and Ready.
	Bridge	Aye, Aye.

This is the proper procedure for testing the sound-powered telephone circuit upon first manning a circuit or after a long period of silence. In this example, assume that the ship has been called to general quarters, and CIC is reporting that all stations in CIC are manned and equipment operating normally.

Combat	Bridge	At Time One Four Three Zero Ship Will Execute Corpen Zero Niner Zero. No Change in Speed.
	Combat	Aye, Aye.

This is a case of the Bridge keeping Combat informed of intended changes in course and/or speed. Notice that the transmission is brief and clear, yet it includes all necessary information.

Bridge	Combat	Surface Contact — One Eight Five — Four Two Thousand.
	Bridge	Aye, Aye.

This is an example of reporting an initial radar contact. Notice that it tells what we see and where it is. Other necessary data on any contact are the time of observation and where the contact is going. The time is obvious because there has been a delay of only a few seconds from the time of observation. We need about 3 minutes to supply additional information such as where the contact is going (course and speed) and what the movement is in relation to our own. Such information is supplied as soon as it becomes available. Notice also that it is not necessary to speak the words "bearing," "range," or "yards." Bearings are always true unless modified by the word "relative."

Bridge	Combat	Surface Contact — One Eight Five — Designated Skunk Alfa
	Bridge	Aye, Aye.

Having given the Bridge the initial contact report, Combat keeps the Bridge informed of changes in position of the contact.

CONTACT DESIGNATION

In the foregoing report, the contact has been reported by radiotelephone to the OTC who has designated it Skunk Alfa. Letters are used to identify surface contacts — Alfa, Bravo, Charlie, etc. Numerals are used to identify air contacts — Bogey One, Two Three, etc. OTC normally makes all original designations. After a contact has been given a designation, all transmissions pertaining to it must include the designation for identification. "Skunk" is the code word for unidentified or enemy surface contact. A Skunk, upon positive identification, may be found to be either friendly or enemy. The code word "Bogey" is used to report unidentified aircraft. The term "Friendly" is used for all contacts, both air and surface, which have been positively identified as friendly.

Bridge	Combat	Skunk Alfa — Course Two Niner Zero — Speed Two Five.
	Bridge	Aye, Aye.

In this example, presumably, we have 3 minutes of plot and a fairly accurate estimate of the course and speed of the contact. Notice that the words "course" and "speed" are used. (As a general rule, the words "course" and "speed" are used when giving that information. It is seldom necessary, however, to use the words "bearing," "distance," "yards," "feet," or "altitude.")

Bridge	Combat	Skunk Alfa — One Eight Two — Four One Thousand — Two Small — Checks Negative.
	Bridge	Aye, Aye.

Here additional useful information is supplied on Skunk Alfa. From the size and appearance of the pip, it appears to be two small ships. It "Checks Negative." (The term "Check Contact" or "Check Bogey" is a standard order to interrogate for IFF response and report results, whether friendly or enemy. "Checks Negative" means that the radar operator did interrogate the raid and observed no IFF response — negative results.)

Bridge	Combat	Skunk Alfa — CPA — Zero Niner Zero — Four Four Hundred — Time One Two Four Three.
	Bridge	Aye, Aye.

This report provides the Bridge with additional valuable information on Skunk Alfa — the bearing, range, and time of the closest point of approach of the raid to our ship — provided both ships remain at their present courses and speed.

Bridge	Combat	Skunk Alfa — One Eight Zero — Four Four Six Zero.
	Bridge	Aye, Aye.

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In the previous transmissions, all ranges were exact multiples of hundreds or thousands; here the range is not an exact multiple and so it is given digit by digit in accordance with the basic rule for pronunciation of numerals.

Combat	Bridge	At Time One Four Four Five Ship Will Execute Three Three Zero Corpen — Speed Two Seven.
	Combat	Aye, Aye.

(Another example of the Bridge keeping Combat informed of course and speed changes. Notice the pronunciation of the time — Time One Four Four Five.)

Combat	Bridge	Watch Skunk Alfa.
	Combat	Aye, Aye.

This is a short, clear transmission. "Watch" is a standard order which tells us to observe and track a raid which has previously been reported and to report any material changes, such as changes in course, speed, etc. If the contact continues to track as indicated by previous report, additional reports of its position are not necessary, unless it is apparent that the contact is becoming dangerous and appropriate action is not being taken.

Bridge	Combat	Air Contact — Two Six Zero — Eighty — Twenty Thousand — Time 1246 — May Be Search Plane Eight Zulu Ramrod Returning
	Bridge	Aye, Aye. Keep Bridge Informed.
	Combat	Aye, Aye.

This is an initial report on an air contact — what it is, where it is in bearing; distance, altitude, and time, followed by additional available information. Eight Zulu Ramrod is the radio call of a search plane which we know should be somewhere in that area. Here we may use the term "Bogey." Notice again that we do not speak the words "bearing," "distance," "miles," "altitude," or "feet." It is not necessary. Since this is a standard procedure, the words are implied and obvious.

Bridge	Combat	Air Contact — Two Six Zero — Squawking Mode Three — Identified by Radio as Eight Zulu Ramrod.
	Bridge	Aye, Aye.

The term "Squawking Mode Three" comes from NWIP 31-3 or NWIP 31-6. It means that the radar operator has interrogated for IFF response and that the contact responded with Mode Three. Remember that when we use code words, we must be sure that all concerned understand them. If they are not understood we must use the plain language equivalent. We must remember always to say what we mean in clear, brief language which everyone understands.

Bridge	Combat	Skunk Alfa Faded — One Seven Five — Four Four Thousand.
	Bridge	Aye, Aye.

The term "Faded" is another standard expression which indicates that a radar contact has disappeared from the scope.

Judging from the examples given, you can see that to be a good telephone talker calls for a lot on the ball. A talker who does not know his ship or his nautical terms, the brevity code words, and standard sound-powered telephone procedure and phraseology is a dangerous link in the communications chain. If ship's speech is new and unfamiliar to you, make it your business to learn the correct terms.

QUIZ

1. What is a basic requirement of every member of the CIC team?
2. How do we achieve speed and teamwork in CIC communications?
3. By what means does the radar operator send information to CIC?
4. For what reason is the MC system used only for passing initial contact reports and other emergency communications?
5. What is the value of communication console equipment?
6. What energy produces electrical impulses necessary to operate a sound-powered circuit?
7. When manning a sound-powered telephone circuit, when is the headset tested for satisfactory operation?
8. In the event that a sound-powered telephone headset transmitter becomes defective under conditions that prevent repairing or replacing it at once, how can communications still be maintained?

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9. Why is it necessary to keep unused jack boxes covered at all times?
10. In general, who is charged with the maintenance of sound-powered telephones?
11. Name three characteristics of a good talker.
12. What is the designation of the Captain's battle circuit?
13. If you were a talker on the Captain's battle circuit during General Quarters and the circuit should become damaged, what circuit would you shift to?
14. Describe the basic form for transmitting a message by sound-powered telephone.
15. What do the procedure words Aye, Aye mean?
16. In what book can you find operational brevity code words?
17. How can Radarmen avoid errors in transmitting numerals on the sound-powered telephone?
18. How is time transmitted on sound-powered telephones?
19. How are difficult words transmitted on the sound-powered telephones?
20. What information should the initial radar contact report contain?
21. How are surface contacts designated?
22. How are air contacts designated?

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CHAPTER 13

LOGS, RECORDS, REPORTS, AND PUBLICATIONS

WHY LOGS, RECORDS, AND DISPLAYS ARE KEPT

As a result of radar and radio communications, the amount of information available to the captain of a ship is too much for a single individual to handle. In addition to this, the speed of aircraft has decreased the time in which the captain may evaluate the information and act on it.

Think for a moment of the problems which might confront the captain of a ship during an engagement. First, there are reports from the radar operators—the bearings, ranges, estimation of size, and so forth. Then the radar information is plotted in CIC and the courses, speeds, and probable intentions furnished to the captain. Besides these, there are position reports of all the other ships in his disposition.

Reports and orders would continually flow in over the various radio circuits. Messages by flashing light, flag hoist, or any other visual method would also be coming in. The sonar gear may pick up contacts. Undoubtedly there would be numerous friendly aircraft in the vicinity, carrying out various missions of search, reconnaissance, support, and interception. The positions of these planes might be reported by both lookouts and radar.

Air search radars would pick up all aircraft within range and furnish bearings and ranges, while surface search radars would have numerous contacts.

In addition to all the reports talked about so far, the captain would receive reports from engineering, gunnery, and damage control stations.

As various attacks develop, the captain has to plan the best possible course of action and then carry it out efficiently. With all this material on hand, the captain has a tremendous amount of information on which to base his decisions. But how can one man receive all these reports, sift the good from the bad, the urgent from the nonessential, and then decide logically what move to make?

The answer, of course, is that he can't. There is just too much information available. But if all sources of combat information report to one place aboard ship, there to be visually displayed, interpreted, evaluated, then passed on to the command, the problem can be solved. As you know, that is exactly what CIC does.

The great advantage of having combat information visually, is the continuous record of surface, air, and underwater action it provides.

SOURCES OF INFORMATION

Consider the various sources of information available to CIC: radar furnishes not only most of the information concerning the position of your own ship and planes but also those of the enemy; lookouts supply position information of objects sighted visually near your ship; sonar equipment determines the range and bearing of objects that can neither be seen by lookouts nor detected by radar. In addition to these sources, electronic countermeasures equipment supply information concerning the bearings of enemy radios and radars.

Position information obtained by other ships and aircraft of our force may also be communicated to CIC.

The identity of any contact whose possibilities have been determined is checked by one of several sources. You can tell whether the contact is friend or foe by IFF, by visual identification, by visual recognition signals, by sonar recognition signals, or by the maneuvers of the contact.

Besides this "on the spot' information, there is background data of a general nature. This includes the plans for the operation, the objectives, and the tactical disposition of own forces and aircraft. The characteristics of own ships and aircraft as well as those of the enemy are valuable pieces of information that CIC does not overlook. Add to this the habits and past performances of the enemy, navigational and weather

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information, sonar conditions, and intelligence reports, and you begin to see the wealth of information gathered in CIC.

HOW THE INFORMATION IS DISPLAYED

Collecting information from all available sources is only one of the functions of CIC.

You know from studying chapter 3, that CIC displays the information coming into CIC. That chapter discussed some methods of displaying CIC collected data. These methods are: summary plot, geographic plots, surface plots, formation diagram plots, strategic plots, AA coordination plots, charts and status boards. Generally these displays are used to record and display information of a temporary nature only.

IMPORTANCE OF LOGS

Another method of recording information in CIC is in a notebook or standard ledger. You will find that many logs, as these notebooks are called, are required to provide a permanent, continuous record of the operations of a ship. In general, the information contained in these logs may be divided into three classes: (1) personnel; (2) equipment; and (3) operation.

Regardless of the category or type of log, its purpose is to provide a complete and accurate performance and operation record for evaluation, for use in writing reports, and for positive proof that certain things were done, or that certain events occurred at a certain time. For example, these CIC records may be used to reconstruct a situation in case of an accident, especially where the witnesses to the accident are killed. A training record can be invaluable to show the amount and kind of training the men in your division have received, and how each individual stands in relation to others. A supply log can be a great help when preparing requisitions for supplies and keeping track of the number of items on hand. A properly maintained radar performance log can aid immensely in making out monthly electronic performance and operational reports.

CIC LOGS

Who is responsible for maintenance of logs in CIC? Specifically, the CIC officer has the overall responsibility for all logs in CIC, but he delegates (but does not relinquish) this responsibility temporarily to CIC watch officers of the team. The specific entries, however, will be made by you when assigned duty as log keeper. For example, the CIC watch officer is responsible for the proper maintenance of radiotelephone logs, but the radiotelephone operator makes the entries in the log. You may be assigned duty as log keeper on any log kept in CIC.

It is not within the scope of this chapter to list and describe all of the logs which you may be required to keep. The number and types of logs will vary from ship to ship. The following logs, however, are presented as the minimum recommended for adequate records in any CIC.

CIC WATCH LOG

The CIC watch log should be a complete and accurate chronological account of both routine and unusual events pertaining to the CIC watch. Normally the log is kept by the CIC supervisor, but in some cases the CIC watch officer will make all the entries. The log can be printed or written in longhand in approximately the following form.

Initial Entry

Starting at 0000 local time, the CIC supervisor, assuming he is maintaining the log, should record the CIC watch officer's name at the top left of page, his own name at the top right side, and the watch section under his name. Then follows the equipment in use, in standby status, or out of commission; tactical data such as formation, formation axis, ship's station assignment, ship's course and speed, special guard assignments; and any other unusual or special data reported to him by the "off-going" watch supervisor. The "on-coming" supervisor should read the captain's night order book and make reference to any unusual or very important comments contained in the order book.

In addition to the normal running account of the watch, on the mid watch you should begin your log by entering a full description of the activity in which your ship is presently engaged. This procedure provides valuable reference for commencing the work of the day. A sample entry on the 0000 to 0400 watch might read like this:

> 00-04 Steaming in company with Task Group 58.1, composed of CarDiv 1, CruDiv 3, and DesRon 5 plus USS Madison (DD 425) and USS Charles E. Brannon (DE 446), enroute from Pearl Harbor, Hawaii to Guam, M. I. (Operating at sea off coast of California) Op Plan CTG 58.1 is in

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accordance with CTG 58.1 USS Rochester (CA 139). Rochester is guide, bearing _____, distance_____yards. Conditions of readiness two and material condition _____ set. Ship darkened (except for running lights). Radar guards are ALFA USS Charles R. Ware (DD 865) BRAVO, USS Hawkins (DDR 873) and so on.

NOTE: On succeeding watches, the first entry is "Steaming as before."

The captain's NIGHT ORDER BOOK is the captain's instructions to the watch. Although actually addressed to the officer of the deck, its contents must be equally familiar to CIC personnel, whether or not they apply to CIC.

STANDING NIGHT ORDERS are usually posted inside the front cover of the night order book. Each day, on a separate page, the captain inserts a description of the general situation at the end of the day, and any special orders (called CURRENT ORDERS) which apply to succeeding watches.

The OOD, and usually the JOOD, the CIC watch officer, and the CIC watch supervisor are required to initial the current night orders to signify that they have read and understood them.

Chronological Entries

During the course of the watch all events of special interest should be recorded: contacts, bearings, ranges, courses, speeds, CPA's, and fades; directions to CAP to intercept BOGIES; the gist of contacts with enemy forces; equipment casualties or changes of status; courses, speeds, and other tactical changes; the gist of important reports transmitted, or orders received on internal circuits; and other occurrences of interest which are not normally recorded in other CIC logs.

Since the CIC watch log contains much of the same type information as the Quartermaster's notebook, the entries can be made in the same form.

The following sample entries are offered as guidance in standardizing keeping of the log. They are taken from *Instructions for Keeping Ship's Deck Log,* NavPers 15876. Such a list of samples, of course, cannot all be inclusive, nor can they be considered the only acceptable entries. Any entry that is complete, accurate, clear, and in standard naval phraseology will be acceptable.

ABBREVIATIONS.—In general, abbreviations in the CIC watch log are limited to those generally accepted throughout the naval service because of long and continued usage. The following is a partial listing of the more commonly used abbreviations:

c/c	. . . . . Changed course
c/s	. . . . . Changed speed
CPA	. . . . . Closest point of approach
OCE	. . . . . Officer conducting the exercise
OOD	. . . . . Officer of the deck
OTC	. . . . . Officer in tactical command
SOP	. . . . . Senior officer present
SOPA	. . . . . Senior officer present afloat

COMMAND AND BUREAU ABBREVIATIONS.—DesDiv 21, ComDesDiv 21, VC, BuPers, and so on.

AIR OPERATIONS.—The following are some samples of entries that might be made in the CIC watch log on a carrier:

1000 Flight quarters.
1005 Commenced launching aircraft for (carrier qualification) (refresher operations) (group tactics), etc.; base course_____. Speed_____.
1025 Completed launching aircraft, having launched 40 aircraft.
1035 Commenced recovering aircraft; base course_____. Speed_____.
1035 Commenced maneuvering, on various courses (and speeds) while recovering (launching) aircraft (while conducting task group (force) flight operations).
1055 Completed recovering aircraft, having recovered 40 aircraft.
1143 Man overboard: one of the plane handlers fell overboard on the port side—latitude 36° 50' N, longitude 74° 31' W.
1144 USS Harlan R. Dickson (DD 708) and helicopter commenced search for man.
1146 Man recovered by helicopter and delivered (on board) (to USS Midway (CVA 41)).
1215 Secured from flight quarters.

NOTE: During flight operations, log the base course and speed. Minor changes may be covered by: "Maneuvering on various courses . . . etc."

SAMPLE DESTROYER ENTRIES

2100 Maneuvering on various courses to take plane guard station No._____on_____; lighting measure _____in effect.
2100 On station.
2115 Commenced flight operations.
2210 A4D type aircraft crashed into sea off starboard bow; maneuvering on various

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courses at various speeds to recover pilot.
2214 Recovered pilot.

ENTRIES CONCERNING DRILLS AND EXERCISES SUITABLE FOR ANY SHIP.

1100 Exercised at general drills.

ABC ATTACK:

1140 Atomic attack imminent; set condition CIRCLE WILLIAM.
1500 (Simulated) Atomic (underwater) (air) burst; bearing_____ distance_____ yards; maneuvering on various courses at various speeds to avoid base surge and fallout.
1530 Rejoined formation and took station _____in formation_____; axis, course, speed, etc.

FUELING:

1100 Formed fueling formation _____.
1100 Left station and maneuvered to standby station astern of USS Caloosahatchee (AO 98).

FORMATION:

0700 Maneuvering to take station_____in formation_____; axis_____, course _____, speed_____knots. Guide is USS Rochester (CA 124) in station_____.
0800 Rotated formation axis to_____.
0900 Formation changed from 40Z to 51V. New course and axis_____, speed _____knots. Formation guide is USS Columbus (CA 74) in station_____.

OFFICER IN TACTICAL COMMAND:

0900 ComCarDiv 4, embarked in USS Midway (CVA 41), assumed OTC.
1000 Commanding officer, USS Franklin D. Roosevelt (CVA 42) was designated OTC.

NOTE: Log all shifts of tactical command. When the OTC is the commanding officer of your vessel, use the following terminology: "OTC is commanding officer, USS *Franklin D. Roosevelt* (CVA 42)." In every case, use command title of OTC, not his name and rank: for example, ComCarDiv 2. State on which vessel the OTC is embarked.

RENDEZVOUS:

0800 USS James C. Owens (DD 776) made rendezvous with this vessel (the formation) and took designated station (took station in the screen) (took plane guard station).
2200 Made rendezvous with TG 19.9 and took designated station number_____in formation 40R, with guide in USS Salem (CA 139) bearing 095, distance 2400 yards, formation course_____, formation speed_____, axis,_____. OTC is ComCarDiv 4 in USS Midway (CVA 41).

TACTICAL EXERCISES:

1000 Commenced division tactical exercises. Steering various courses at various speeds (in Area HOTEL) (conforming to maneuvers signaled by ComDesRon 12) (on signals from ComDesRon 12).

ZIGZAGGING/SINUATING:

1300 Commenced zigzagging in accordance with Plan No._____base course_____.
1500 Ceased zigzagging and set course_____.
1600 Ceased steering sinuous course and set course_____.

NAVIGATIONAL ENTRIES:

1600 Anchored in Area South Hotel, Berth 44, Hampton Roads, Virginia, in 4 fathoms of water, mud bottom, with 30 fathoms of chain to the port anchor on the following bearings: Fort Wool 040, Middle Ground Light 217, Sewalls Point 072, Ships present:_____SOPA ComCruDiv 2 in USS Canberra (CAG 2).

CONTACTS:

1621 Skunk 090, 28,900 yards. Designated Skunk ALFA.
1629 Skunk ALFA (bearing)_____(range) _____on course _____speed knots. CPA_____, distance_____ miles.
1636 Skunk ALFA identified as USS Knapp (DD 653) by lookouts.
1715 Sonar contact bearing 172, range 2500 yards.
1717 Contact classified as possible submarine. Commenced attack (tracking) (investigating).
1721 Contact regained bearing 020, range _____. Oil slick reported sighted by lookouts on that bearing and range. Commenced re-attack.

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NOTE: On some ships all contact information from own radars is recorded in a log called radar performance log or radar contact log. However, any unusual or important contacts should also appear in the CIC watch log.

Final Entry

The final entry for a particular watch should include data of value to the "on-coming" watch and for permanent record, and finally, the "off-going" CIC watch officer should inspect the log and place his signature at the bottom right of the page just after the entries.

RADIOTELEPHONE LOGS

CIC must have a complete picture of the tactical situation at all times. The CIC team is charged with the responsibility of keeping the captain informed of the location, identity, and movement of all ships and aircraft within the area. Much of the information CIC needs to present a full picture comes from sources outside the ship. This information flows into CIC over voice radio circuits. For example, an order to change fleet course comes over the primary tactical and maneuvering circuit from the task group commander, while a radar guardship reports an enemy contact over the radar reporting channel (combat information net).

The effective edition of *U.S. Naval Communication Instructions* states that complete logs shall be maintained on the following nets:

1. Maneuvering net.
2. Task unit (or group or force) chain-of-command net.
3. Combat information net, with the exception that standard abbreviations similar to those used to record data on CIC status boards may be logged.

Modified logs may be maintained on all other circuits and nets. The completeness of coverage and degree of textual detail will vary with the type of ship, availability of personnel and the category of information passing through the net or circuit. The ultimate decision as to the completeness of logs on other circuits rests with the commanding officer.

Radio logs can be kept in freehand or with a typewriter. In case freehand is used, the log is generally written in a large notebook. After you have listened to several transmissions you will discover that they all follow the same form. This set form is called radiotelephone procedure. Radiotelephone procedure is discussed fully in *Radarman 3 & 2*, Vol. 2. The more familiar you are with this prescribed procedure, the easier it will be to copy the transmissions.

If desired, prowords may be logged by CW equivalents (prosigns). Some are shown in the examples to follow.

RADIOTELEPHONE LOG ABBREVIATIONS

Although voice transmissions are spoken slowly and clearly to make sure the message gets through, you may find it difficult, particularly if you are a slow writer, to copy accurately. To make it easier, a number of abbreviations (besides the prosigns) have been developed that allow for shortcuts in writing voice transmission. Following are some of the more important prosigns and abbreviations. In the left-hand column are the words you hear on the circuit, and in the right-hand column are the corresponding shortcuts to be used in writing the message down.

You Hear	You Write
From	DE
Message for you	M4U
Acknowledge	Ack.
Break	BT
Roger (message received)	R.
Wilco (will comply with the order received)	Wilco
Course	Cus.
Corpen	Corp.
Speed	Sp.
Position	Posit.
Starboard	Stbd.
Distance	Dist.
Bearing	Brg.
Range	Rg.
Emergency	Emerg.
Affirmative	Afirm.
Negative	Negat.
Standby	Stdby.
I say again	$\overline{\text{IMI}}$
Say again	$\overline{\text{IMI}}$
Execute	$\overline{\text{IX}}$
Execute to follow	$\overline{\text{IX}}$
Immediate execute	Immediate $\overline{\text{IX}}$
Tack	—
Time of execution	TOX

To avoid any possibility of confusing zero with the letter O, zero is distinguished by drawing a slant line through it, thus, Ø; for the same reason, the letter Z is written with a small bar, as Z to distinguish it from the numeral 2.

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SAMPLE OF A SCREEN COMMON RADIO-TELEPHONE LOG

Table 13-1 is a sample for keeping a maneuvering net (screen common circuit) radiotelephone log, showing entries for:

1. Immediate Execute Method.—Line 1 details the log entry for an immediate execute message.
2. Delayed Execute Method.—Lines 2 and 6 show the entries for a delayed execute message. The first portion (line 2) is entered as received, leaving the TOX (time of execute) blank. When the command is finally executed by the message recorded in line 6, the time of execution in line 2 is filled in.
3. Administrative Message.—All message data plus the text is logged. There is no execution involved, therefore no entry in the TOX column.
4. Change of Watch.—Each operator signs in and out, as shown in lines 4 and 5. Messages for each new day are separated from previous log entries and the date indicated.

RADAR PERFORMANCE LOGS

A separate operation log, or radar performance log, should be kept on each piece of radar equipment. This log is kept in a notebook the same as the other logs, with chronological entries including the name of the operator on each watch; the time the equipment was turned on, off, or placed in standby status; material casualties and repairs; maintenance data, and other information required by the electronic repair officer for adequate machinery history.

Value Of The Radar Performance Log

The radar performance log supplies data on past performances that will aid technicians in maintaining the set. This provides an excellent comparison between the actual, and the expected performance of the gear. Upon relieving the watch, the oncoming operator can tell by a glance at the log whether the gear is operating normally. The reports contained in the operator's log serve as a reference for material reports. This running record of what happened on the watch also provides a background of information which is used by the CIC watch officer when he writes the official CIC log at the end of the watch.

When making an entry in the log, always insert the following: when the receiver was tuned, calibration of the scope checked, errors of calibration if any, and the initial range and bearing of each contact. After the plotters have reached a solution of the course and speed of the contact, enter this information along with the time and point of closest approach of the target. If the contact were sighted visually, note in the log the type of target and the number making up the contact. Be sure to enter the appearance of the pip on the scope using the E-unit to indicate signal strength. After noting in the log the range and bearing at which the target disappeared, conclude the entry with a brief description of how the radar performed.

A properly maintained radar performance log will help immensely at the end of each month when the electronics performance and operational report has to be sent off the ship. It will be to your advantage to enter, from watch to watch, such items as echo box ring time, maximum detectable radar range with E-unit, minimum reliable radar range with E-unit, and type of target. Numbers are given for type of target: 1, large plane; 2, small plane; 3, group of ships; 4, ship; 5, submarine; 6, buoy; 7, rain squall; 8, blimp; 9, land; 10, iceberg; 11, miscellaneous small targets. If the radar is an altitude determination radar, enter all as mentioned, plus altitude at maximum detectable radar range. Also include in the log the voltage standing wave ratio when possible.

RADAR NAVIGATION LOG

While steaming in restricted waters, entering or leaving port, passing through narrow channels, or engaged in naval gunfire support, keep a chronological record in ledger form on all targets, bearings, ranges, courses, speeds, set, drift, and other pertinent information. Maintain chart overlays in the permanent files. Each overlay should be identifiable with appropriate entries in the log.

RADAR COUNTERMEASURES LOG

The radar countermeasures log includes the operator's name and complete identification of all signals received and analyzed, including time, frequency, pulse width, antenna rotation rate, beam width, polarization, lobe switching, bearing, range and originating station, if known, and

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Table 13-1.—Radiotelephone Log Example.

CIRCUIT SCREEN COMMON

	TO	FM	TIME	TEXT	TOX
(Line 1)	BULL RUN	MAGNIFY	23Ø2	IMMEDIATE EXECUTE BREAK TURN 18Ø BREAK I SAY AGAIN TURN 18Ø STANDBY EXECUTE	23Ø2
(Line 2)	BULL RUN	MAGNIFY	2335	EXECUTE TO FOLLOW BREAK 135 CORPEN TACK KILO CORPEN OVER	ØØØ5
(Line 3)	BULL RUN	MAGNIFY	2345	ROUTINE TIME Ø12315Z FROM MAGNIFY TO BULL RUN BREAK (TEXT) BREAK OVER	
(Line 4)				W. G. THEBUS, RDSN.	
(Line 5)	2 MAY 1961 - R. E. REDDICK, JR., RD3				
(Line 6)	BULL RUN	MAGNIFY	ØØØ5	135 CORPEN TACK KILO CORPEN STANDBY EXECUTE	ØØØ5

SAME RADIOTELEPHONE LOG USING CW EQUIVALENTS AND ABBREVIATIONS

	TO	FM	TIME	TEXT	TOX
(Line 1)	BR	MAG	23Ø2	IMMEDIATE $\overline{IX}$ $\overline{BT}$ TURN 18Ø $\overline{IMI}$ TURN 18Ø STANDBY $\overline{IX}$	23Ø2
(Line 2)	BR	MAG	2335	$\overline{IX}$ $\overline{BT}$ 135 CORPEN - K CORPEN $\overline{BT}$ K	ØØØ5
(Line 3)	BR	MAG	2345	R - Ø12315Z FM MAG TO BR $\overline{BT}$ (TEXT) $\overline{BT}$ K	
(Line 4)				W. G. THEBUS, RDSN	
(Line 5)	2 MAY 1961			R. E. REDDICK, JR., RD3	
(Line 6)	BR	MAG	ØØØ5	135 CORPEN - K CORPEN STANDBY $\overline{IX}$ K	ØØØ5

NOTE: The words TO, FM, TIME, TEXT, and TOX should be printed at the top of each page of the log. This saves writing DE and M4U and allows extra time for writing the text.

any other characteristics noted. The latitude and longitude of your ship at the time a signal is detected is particularly important. A record of jamming, both by friendly or enemy forces, also should be kept in the log. You will learn more about the ECM log when you study Radarman 3 & 2, Vol. 2.

DISPOSAL OF LOGS

All logs that are kept in CIC may be disposed of in 6 months; however, if they contain information that concerns an accident, such as running aground, collision, and the like, they must be retained on board for a period of 3 years. Never destroy a log without permission.

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ALTERATIONS IN THE LOGS

Logs that are kept in CIC must be accurate. Therefore, nothing must appear in them which might imply that entries had been changed, or that material was added. For this reason no blanks must be left where entries might be made later.

For the same reason the logs must NEVER be altered by ERASURE. If you make an incorrect entry, draw a single line through it, and enter your initials in the margin. Write the correct entry in immediately afterwards, if possible. If not, write it in the first available space, label it with the proper time, and indicate by an arrow the place where the correction should appear.

RECORDS

The recording of data as described is maintained by all personnel in CIC, from the RDSN to the CIC watch officer. There are other logs or records besides the ones already discussed that will have to be kept.

TRAINING RECORDS

On becoming a petty officer, you will realize immediately that you have more authority and responsibility. Therefore, you will be required to exercise more leadership than has been required of you up to now.

One place where you will notice the difference is in your new relationship to officers and your juniors. You know from past experience that officers usually instruct the senior petty officer on the general operation to be performed, and that the senior petty officer assigns the work and gives the instructions to the men.

You may be assigned the responsibility of training your juniors and maintaining a record showing the progress of these men.

Many times you will find the instructions given by your division officer in written form. These may be in the form of standing operating procedures, instructions or notices, or even checkoff lists. These are excellent training references for you to use if you are assigned the duty of training. Any problems that arise are referred to the senior petty officer who either handles them himself or takes them to his division officer. You may be that senior petty officer, so you must be ready to assume the responsibility of the job.

One important function you will most likely assume as a senior petty officer is to start evaluating subordinate personnel for advancement in rate. To give you an idea of how this is done, let us review an enlisted performance evaluation process.

ENLISTED PERFORMANCE EVALUATION

The purpose of this procedure is to provide a standard method of processing enlisted performance grades.

Importance of Marks

In assigning grades, your superior officers will usually follow your recommendations. However, if a question arises as to why you assigned a certain mark you should have material to back up your recommendations. The best way to do this is to keep a log of the training each individual has had plus the grades on any quiz he has taken after a training session. Do not try to rely on your memory; these grades are too important to be passed along without care.

These marks mean a great deal toward advancements, awards, discharges, reenlistments, selection for special programs, projects, courses of instruction, reduction in rating for incompetence, and propriety of early separation by administrative discharge of an individual.

The marks assigned must reflect the individual's performance in comparison with others of similar rate and experience, and the word description must support the marks assigned. In the remarks section, specific accounts of individual accomplishments will carry vastly more weight than broad generalities.

Similar marks must not arbitrarily be assigned to all men in the same pay grade. This is a lazy man's habit which penalizes outstanding men and degrades the promotion multiple system.

You consider each man for his contribution—not for his personality alone. There is a saying that "you never know the good men in an organization until they are gone." This implies that the quiet individual who never says much and is never in trouble is really doing a good job—if you really think about it. It is because of his quiet personality and because he does everything expected of him, that he is not noticed.

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Responsibilities

The commanding officer is responsible for the evaluation of all personnel assigned to his command.

The executive officer will review all marks recommended and act as authenticating officer when directed by the commanding officer.

The head of department will review all marks recommended by division officers and petty officers and make any changes that he sees fit.

Division officers will initiate recommended grades for the senior petty officers in their divisions.

Division leading petty officers will evaluate the junior petty officers and nonrated men under their supervision. Such evaluations will be reviewed by the division officer.

Grades are assigned semiannually, upon detachment of an individual, upon closing out his service record, and such other times as directed by current BuPers directives.

RECORD OF PRACTICAL FACTORS

As a Second or Third Class Radarman, you will aid the division officer in making the entries on each man's *Record of Practical Factors*, NavPers 760 (RD). This record (fig. 13-1) has two parts: military requirements for enlisted personnel, and professional requirements for Radarmen.

As each man demonstrates his proficiency in each of the practical factors listed on the form, the fact is certified by completing the DATE and INITIALS columns.

Instructions for maintaining the form are shown at the top of the front page. Make sure that your training program covers all the requirements, both military and professional. Above all, see that each man has a personal copy of the form.

When you get a new man in the division, your first step should be to check his 760 to ascertain what factors he has mastered. Once you have determined his past experience, you can assign his stations and give him instructions commensurate with his background.

ASSISTING YOUR DIVISION OFFICER

The operational reliability of the CIC is closely related to the effectiveness of its administration. The watch, quarter, and station bill, which is the basis for assigning duties to personnel in CIC, should therefore be completed with considerable care in order to obtain the most effective organization. By virtue of being a Radarman 3 or 2, you may be assigned the duty of a section leader. Nobody in the gang should know the men in your section better than you. In view of this fact you may be called upon to help your division officer in making out the watch, quarter, and station bill. This you will do by advising him what man you think is best suited to fill these positions required in CIC. In addition, you may be called upon to assist your division officer or CIC officer in writing the standard operating procedures for the various CIC functions which your particular ship performs. Once written, these procedures provide you with an excellent basis for training your gang, as well as ensuring that a particular function is always performed according to the standard procedure, as determined by the individual ship.

Keep a training record (in a notebook) of completed and proposed training, because a record provides a good indication of the training needs for CIC personnel.

None of the individual tasks performed in CIC is particularly complex or difficult to well-trained personnel, but the coordination of the efforts of all personnel assigned to produce effective functioning can be achieved solely by an effective and well-rounded training program.

Training

The smooth-functioning CIC is a team—and teamwork is perfected by drill. In order to gain flexibility by which each man can perform in several assignments, you must train your men in standard methods of operating detection equipment, plotting, and using communication equipment. This information is covered in detail in the NWP's and NWIP's which form the basis for a practical training program. If you are assigned the duties of training petty officers for your section, be sure to include frequent drills in operating under casualty conditions. Ensure that each member of the team knows what action to take in the event of fires, personnel injuries and loss of or damage to radars, radios, MC units, S/P telephones, lighting, DRT, gyros, power, plots, and status boards.

Checkoff Lists

As discussed in a previous chapter the POMSEE program contains checkoff lists for all

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RECORD OF PRACTICAL FACTORS

NAVPERS 760 (RD) (Rev 3-56)

INSTRUCTIONS

1. *As proficiency in each practical factor listed here is demonstrated, an entry is to be made in the DATE and INITIALS columns by the supervising officer.*
2. *Waivers may be granted for specific qualifications in accordance with current BuPers Instructions.*
3. *If a man demonstrates proficiency in skills considered to be within the scope of his rating but not listed in this list of minimum qualifications, an appropriate entry should be made on this form in the spaces provided unless the information is entered elsewhere in the man's service record.*
4. *A copy of this form is to be held by the division officer or by the appropriate supervising officer of each man in pay grade E-3 through E-6.*
5. *Upon transfer of an enlisted man, the supervising officer's copy of the form is to be signed, inserted in the correspondence side of the enlisted service record, and forwarded.*
6. *As changes in the rating structure and major changes in the Manual of Qualifications for Advancement in Rating, NAVPERS 18068, occur, new forms will be made available. Minor changes in NAVPERS 18068 should be recorded in existing forms in the spaces provided.*
7. *One copy of the printed form should be made available to each man for his personal record and guidance.*

RATING	ABBREVIATION	DATES OF COMPLETION OF PRACTICAL FACTORS CHECKOUT FOR RATE LEVEL
RADARMAN (*Includes Change 9 to NAVPERS 18068*)	RD SN	3 _____ 2 _____ 1 _____ C _____
NAME: RICHARDSON, M. L.	SERVICE NUMBER: 666-11-52	

PRACTICAL FACTORS	RATES	COMPLETED DATE	COMPLETED INITIALS
MILITARY REQUIREMENTS FOR ENLISTED PERSONNEL			
100 PRACTICAL FACTORS			
101 OPERATIONAL			
20. Demonstrate how to use: a. Portable CO_2 extinguishers. b. Hoses, nozzles, and adapters. c. Safety lines and signals.	3	6/14/–	J.E.O.
102 MAINTENANCE AND/OR REPAIR			
5. Field strip, clean, and assemble the service pistol.	3	2/27/–	J.E.O.
103 ADMINISTRATIVE AND/OR CLERICAL			
1. Prepare an indoctrination schedule for a new recruit reporting for duty.	2		
2. Select and organize appropriate subject matter and instruct by the Showing (demonstration) method.	2		
3. Prepare a standard Navy letter.	2		
4. Prepare a detailed work assignment for men in your division.	1		
5. Teach a group, observing the following steps in developing the lesson: a. Setting the objectives. b. Presenting the subject matter. c. Providing trainee application through practical work and drill. d. Summarizing key points. e. Testing trainee achievement.	1		
6. Prepare and administer a written test which includes the following types of questions: a. Essay. b. Multiple choice. c. True-false. d. Completion.	1		
7. Use the following training aids and devices: a. Training films, slides, and transparencies. b. Charts, posters. c. Models and mockups. d. Demonstrators and trainers.	1		
8. Prepare a preventive maintenance schedule for an item of machinery or equipment in your division, considering possible changes to ship employment schedule.	C		
9. Demonstrate ability to conduct instruction by each of the following methods, using subject matter appropriate to each method: a. Telling (lecture). b. Questions and discussion. c. Drill and practical work. d. Written study materials.	C		
10. Plan and supervise on-the-job training program based on: a. Level of trainees' knowledge and skill. b. Degree of skill to be developed. c. Available equipment and training aids. d. Qualifications for Advancement in Rating, NavPers 18068 (Revised).	C		
44 MILITARY CONDUCT			
7. Command a squad in close-order drill.	3		
8. Fire service pistol, observing safety precautions.	3		
9. Relieve a watch armed with pistol.	3		

PRACTICAL FACTORS	RATES	COMPLETED DATE	COMPLETED INITIALS
PROFESSIONAL REQUIREMENTS FOR RD			
100 PRACTICAL FACTORS			
101 OPERATIONAL			
1. Start, stop, operate, calibrate, and tune surveillance and height-finding radar equipment, including associated IFF and target designation equipment, to which assigned.	3	4/29/–	J.E.O.
2. Start, stop, operate, and calibrate remote plan position indicators (RPPI) to which assigned.	3	5/17/–	J.E.O.
3. Adjust parallel motion protractor equipment, position, bug, and make appropriate scale and quadrant setting on dead-reckoning tracer (DRT).	3		
4. Start, stop, and tune radio receivers installed in CIC.	3		
5. Start, stop, and operate transmitter remote control units used for radiotelephony.	3		
6. Distinguish between radar contacts caused by ships, aircraft, and missiles and those caused by natural disturbances.	3		
7. Determine the following contact information from appropriate radar equipment: Range, bearing, altitude, composition, and identification (IFF).	3		
8. Maintain multiple tracks on geographic, summary, and surface plots, including dead-reckoning of air and surface targets.	3		
9. Plot ranges, bearings, and fixes on nautical charts, including dead-reckoning.	3	8/22/–	J.E.O.
10. Set up formations and screens on surface plot by direct reference to current tactical publications.	3		
11. Convert given positions into grid coordinates.	3		
12. Start, stop, operate, calibrate, and tune equipment which may be used for electronic countermeasures purposes and to which assigned.	2		
13. Classify intercepted electromagnetic radiations such as: Radar and/or IFF, jamming signals, guided missile control signals, communications signals (teletype, CW television), and navigational aids signals.	2		
14. Determine the following information from an intercepted electromagnetic radiation signal: Frequency or frequency range, presence of frequency shifting; antenna polarization, antenna beam width, antenna scan rate, presence of lobe switching; pulse width, pulse repetition rate, and bearing.	2		
15. Perform the basic functions of CIC by furnishing information regarding location, identity, and movement of contacts, determined by interpreting information gained from radar and electronic countermeasures equipment and data derived from plots maintained.	2		
16. Transmit, receive, and authenticate on CIC radiotelephone circuits, using standard vocabularies, procedures, and techniques.	2		
17. Perform CIC duties related to navigation and piloting of own ship by plotting own ship's track by radar fix and maintaining geographic plot, applying principles of advance, transfer, acceleration, deceleration and set and drift.	1		

Figure 13-1.—Record of practical factors, NavPers 760 (RD).

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equipment, calls for periodic schedules of inspection (watch, daily, weekly, monthly, quarterly, annually), and for cleaning, checking, replacement, tuning and calibration of equipment. Making sure that these checks are made is another way in which you can assist your division officer. These checkoff lists should be based on the instruction books for the equipment, and should be used in conjunction with the instruction books. Make sure, when you assign men to do these various checks and cleaning jobs, that a record is kept. A proper log of these details will aid you in preparing monthly reports.

Above all, be sure your men observe all safety precautions.

CIC PUBLICATIONS

Much of the information used by CIC comes from publications, operation orders and operation plans. Therefore, all CIC personnel must be familiar with these publications and their contents. Remember, all evolutions performed in CIC have their bases in some doctrinal concept or tactical procedure contained in these publications. Your competency as a Radarman will be based on the facility with which you use them.

Let us discuss the publications which are most commonly used in CIC.

NAVAL WARFARE PUBLICATIONS

The NWP's are the source books for U. S. Navy doctrines. The NWP's are the master books in this series and give the general overall coverage of planning principles and the various phases of operations.

The NWP series is divided into four groups:

Group I, Basic Principles and Planning (NWP 10 through NWP 16 including ATP's 1(A), 2, and 3). These NWP's present the fundamentals and principles underlying the successful prosecution of naval warfare and the planning necessary for its accomplishment. The remaining publications in this group are integral parts of this series by virtue of the fundamental nature of the doctrine they contain.

Group II, Conduct of Naval Operations (NWP 20 through 27). These volumes provide all echelons of command with the overall concepts involved in surface, air, and underseas operations.

Group III, Naval Operating Procedures (NWP 30 through NWP 50). These set forth procedures common to most or all of the forces which are formed for the execution of Group II tasks. In addition, they expand, where necessary, the procedures which may be covered only briefly in Groups I and II.

Group IV, Fleet Exercise and Allied Exercise Publications (FXP 1 through FXP 5, and AXP 1 through 3). Both these series contain exercises necessary for the promotion of proficiency in operating procedures and are designed to provide standard methods for the conduct of exercises, together with the means of evaluating their effectiveness.

NAVAL WARFARE INFORMATION PUBLICATIONS

The Naval Warfare Information Publications (NWIP's) give detailed technical instructions to supplement the doctrine found in the NWP's. The NWIP's bear the same number as their parent books, plus consecutive numbers within their individual series, the two numbers on each book being separated by a dash. Examples are: NWP 16, *Basic Fleet Operational Communication Doctrine,* NWIP 16-1, *Employment of Communications.*

COMMUNICATION PUBLICATIONS

Communication publications are promulgated for use within the Navy, interservice use among various services of the Defense Department, and for combined use with allied powers. In general, the NWP, DNC and CSP series pertain to the Navy; the JANAP series are used jointly by the Army, the Navy, and the Air Force; and the ACP series are for use with allied nations. The communication publications the Radarmen are particularly interested in are:

DNC 5B

This publication furnishes detailed instructions for the employment of naval communications on both the command and operator levels.

ATP-1(A), VOL. II

Contains tactical signals for transmission by flag hoist, other visual methods, or by radiotelephone. It is used constantly in CIC.

Other communication publications of which all Radarmen should have a ready knowledge are: ACP 125, ACP 165, ATP 4, JANAP 119, and NWIP 16-1.

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COMMUNICATION PLANS

Type commanders promulgate communication plans for administrative guidance. Tactical commanders promulgate communication plans as annexes to operation plans or orders. These communication plans clarify, amplify, or modify instructions in basic service publications, and they contain specific instructions on the conduct of communication within the command or during a particular exercise or operation. CIC personnel must be familiar with currently effective communication plans.

TACTICAL PUBLICATIONS

Doctrine for routine operations in the Navy is promulgated in various tactical publications.

ATP 1

Although it is beyond the scope of this chapter to outline ATP 1 in detail it is sufficient to say that it is the single most important publication in CIC. As a Radarman you will need to use it more frequently than any other publication. Therefore, your skill as a Radarman is comparable to your ability to use ATP 1 well; and this ability comes only with a thorough knowledge of the publication itself.

NWP 31

This is another publication with which you should become thoroughly familiar. It is promulgated for the purpose of apprising the Naval Establishment of CIC doctrine, terminology, and operating procedures. The doctrine and procedures are applicable to all tasks and tactical employment.

There are many other publications of value to CIC personnel. Many of them are used daily. The number is too great to list them here, but all are important enough for you to make it a point to investigate the safe in CIC and to browse through each and every one of the publications.

Those tactical publications of more than passing interest to the Radarman are ATP 3, NWIP 31-1, NWIP 31-3, NWIP 31-4, NWIP 31-5, and NWIP 31-6.

The publications we have briefly noted are those which are used daily in CIC. You must be familiar with all those which pertain to your type of ship or to any operation in which your ship is engaged. In addition, you will have access to valuable periodicals like Combat Readiness, and other service technical publications.

CIC SUPPLIES

Another important job you will have as a rated Radarman is preparing requisitions for CIC equipment, parts, and supplies.

REQUISITIONS

Each ship is allotted a quarterly allowance for operation, maintenance, and repair. This allowance is usually divided among the various departments of the ship by the commanding officer.

Since several divisions make up a department, it is necessary that they cooperate when ordering supplies. One division must not order extra supplies and short change another of possibly important items.

How do you know what items to order and the amount? Here is how one petty officer accomplished the job. He obtained a notebook and then consulted various ships' C-I division supply petty officers to find out how many of each item was necessary for a 6-month period. Once the list was made up, all he had to do was keep it current as to what was expended and what was left. He then ordered items as necessary in order to keep a 6-month supply.

A 6-month supply is not too much. Most ships make extended cruises lasting 6 months, and supplies are often difficult to get while overseas.

Request for general stores material (GSM) are prepared on a Request for Issue or Turn-in (DD Form 1150) (see fig. 13-2).

Only one class of material is entered on a particular form. When presented at the GSM issue room, each request is carefully checked to ensure that it has been filled out correctly. When filling out a request, make sure it contains the following information:

1. Department requiring the material
2. Date the request was prepared
3. Signature of the department head or an officer authorized by the department head to sign in his stead
4. Information properly identifying the material requested
5. Quantity required
6. Stock unit of material requested

Consult the *Navy Stock List of General Stores*, if possible, when filling out the requisition. This will enable you to properly identify the material being requested and also to give the stock or class number. Only material in one stock or class can be entered on each stub.

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REQUEST FOR ISSUE OR TURN-IN | X ISSUE | TURN-IN | SHEET NO. | NO. OF SHEETS | 5. REQUEST NUMBER: OPER 251

1. FROM: OPERATIONS OFFICER CVA 111 | 6. DATE MATERIEL REQUIRED: 4-20-- | 8. VOUCHER NUMBER

2. TO: SUPPLY OFFICER CVA 111 | 7. PRIORITY | 9a. POSTED (Initials & date) | b. POSTED (Initials & date)

3. APPROPRIATION SYMBOL AND SUBHEAD | OBJECT CLASS | EXPENDITURE ACCOUNT (From) (To) | CHARGEABLE ACTIVITY | BUREAU CONTROL ACTIVITY NUMBER | BUREAU CONTROL NUMBER | AMOUNT OBLIGATED | JOB ORDER

4. END ITEM IDENTIFICATION | a. NAME AND MANUFACTURER | b. MODEL | c. SERIAL NUMBER | d. PUBLICATION

ITEM NO. (a)	STOCK NUMBER AND DESCRIPTION OF MATERIEL AND/OR SERVICES (b)	CODE* (c)	UNIT OF ISSUE (d)	QUANTITY (e)	SUPPLY ACTION (f)	UNIT PRICE (g)	TOTAL COST (h)
1	GF 7510-266-6712 TAPE, MASKING		RI	5		.31	1.55
	GENERAL PURPOSE, 1 INCH						
2	GF 7520-223-6672 PENCIL, GLASS		EA	144		.13	18.72
	AND CHINA MARKING						

*ISSUE - I - Initial; R - Replacement TURN-IN - U - Unserviceable; S - Serviceable | 10. TOTAL 20.27

11. ISSUE OR TURN-IN OF QUANTITIES IN "QUANTITY" COLUMN IS REQUESTED | DATE 4-20- | BY J. E. Osborne, Ch | 12. RECEIVED QUANTITIES IN "SUPPLY ACTION" COLUMN | DATE | BY

DD FORM 1 JUL 56 1150 (9 PT) 6

Figure 13-2.—Request for issue or turn-in (DD Form 1150).

If the material is not in stock, the request will be canceled, and you will have to submit a new one when the stock of the ship is replenished. If the material is not carried in stock aboard your ship, the supply officer will requisition the material from the nearest available source of supply.

Here again is where your notebook will aid you. In the notebook, keep the correct names and group numbers of items you order frequently, as this will save time. Use your notebook only as a guide to find the various articles. Also use the notebook as an inventory checkoff list so you can reorder before you run out of articles.

GSM Material

The Navy uses a vast number of different items. There are more than 80,000 listed in the *Navy Stock List.* If you need a certain item in the *Navy Stock List,* you must record the correct Federal stock number (FSN), or parts number, and nomenclature on the requisition to obtain the desired item. You can get this information from the *Navy Stock List,* which lists and identifies items of general supplies carried in stock for issue to ships and stations. It contains approximately 75 GROUPS which are further subdivided into about 500 CLASSES. Each class covers items with the same physical or performance characteristics, or those items which are generally requisitioned together.

The *Navy Stock List* gives a short description of each item: specifications, measurement equivalent, usage data, unit of issue, price, and often an illustration. The Radarman must have a general knowledge of procedures for using the *Navy Stock List* to be able to prepare requisitions.

Suppose, for example, you are ordering a heavy-duty connector plug. The first step is to determine which GROUP of material contains connector plugs. They come under Group 59 (Electrical and Electronic Components, Part 3). The alphabetical index at the beginning of Part 3 lists heavy-duty plugs as item 3555. (Item numbers are arranged numerically and are easy to find.) The page of the *Navy Stock List of General Stores* listing this item is shown in figure

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CONNECTOR, PLUG, ELECTRICAL (Cont'd)

Unit of Issue: Each (EA)

Item 3460

Explosion-Proof

Crouse-Hinds Co. or equal.

Delayed-action type; furnished with cable grip and rubber bushing.

Use: In spaces or areas where explosive vapors or mixtures may be present.

Item	Stock No.	Body Material	Cable Opening In.	Rating			Mfr. Cat. No.	Used with Item
				Amp.	Volts	Hp		
	2-WIRE, 3-pole, 1-phase, grounding through shell							
3430	G5935-280-2386	Plastic, with aluminum shell	0.375—0.875	7/30	460/230	1/2—1-1/2	CPH7713	3615-3645
	2-WIRE, 3-pole, 1-phase, grounding through extra pole							
3440	G5935-494-0658	Bakelite	0.375—0.500	15	115/230	1	CPP412	3615-3645
3450	G5935-162-4999	"	.500— .625	"	"	"	CPP512	
	3-WIRE, 4-pole, 3-phase, grounding through shell							
3460	G5935-280-2388	Plastic, with aluminum shell	0.750—0.875	30/60	460/230	5	CPH7734	3665

Safety Type

Appleton Electric Co. or equal.

250 volts DC, 600 volts AC. Aluminum shell; polarized type circuit-breaking plugs with male round contacts.

Packed 1 per carton, 4 cartons per case.

Item	Stock No.	No. of Contacts	Amp.	Cable Opening In.	Mfr. Cat. No.	Used with Item
	GROUNDING THROUGH SHELL					
3485	*G5935-283-4005	2	60	0.750—1.375	AEP6212	3700
	GROUNDING THROUGH EXTRA POLE					
3495	†G5935-283-4006	4	100	1.375—1.75	AEP10423	3690

*Changed from Stock No. G5935-283-3905. †Changed from Stock No. G5935-283-3906.

Locking

Russell & Stoll Co. or equal.

Polarized, male plug with round contacts, grounded through extra pole; with clamp type cord grip. Cadmium-plated steel housing. Locks into connector by twisting.

Item	Stock No.	No. of Contacts	Amp.		Max. Cable Size In.	Mfr. Cat. No.
			250V DC/440V AC	125V DC		
3520	G5935-149-4011	3	10	20	1/2	8013
3530	G5935-149-4192	4	20	30	5/8	8014

Heavy Duty

Crouse-Hinds Co. Catalog No. APJ-10375 (formerly AP10375), or equal.

Aluminum body; 3 polarized round contacts; with cable clamp opening, and grounded type shell. Furnished with gland nut and tapered rubber bushing.

Item	Stock No.	Rating	
		Amp.	Volts
3555	G5935-280-2385	100	250DC/600AC

Figure 13-3. – Page from the Navy Stock List of General Stores.

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13-3. Note the FSN: G 5935-280-2385. Enter this number and descriptive data on the requisition. Letter G indicates connector plug is a general stores item, and 5935 is its CLASS.

Requests For Repair Parts

The procedure for ordering repair parts is similar to ordering GSM material. If the stock number is known, enter it on the DD Form 1150 together with COMPLETE identifying data. If the stock number is not known, you not only will have to fill in the DD Form 1150 but also a Request for Repair Parts (NavSandA Form 302), shown in figure 13-4.

Put the following information, as applicable and available, on the form.

1. Full description of electrical and physical characteristics of item
2. Equipment name, group, and class
3. Manufacturer's reference number
4. Joint Army-Navy military or Army-Navy aeronautical type number
5. Contractor's part or drawing number
6. Navy type number
7. Army Signal Corps stock number

WORK REQUESTS

Repairs to ships are generally made by the ship's force, repair ships or tenders, and naval shipyards. Individual ships are directed to make every effort toward self-maintenance to reduce the number of overhaul periods. In other words, a ship's force should accomplish as much repair work as possible.

Shipboard Work Requests

In order that naval shipyards may be fully prepared to commence work immediately upon arrival of ships, and complete the required work during the overhaul period, the shipyard must receive requests no less than 30 days prior to commencing the overhaul period. The work requests will be forwarded via the type commander, and because of this the requests usually have to leave the ship 90 days in advance of the overhaul period.

Your job may be to make out work requests on equipment in CIC spaces for submission to the CIC officer.

Prepare the requests so as to furnish the shipyard with sufficient data to permit advance planning and estimating. Describe, COMPLETELY AND CORRECTLY, existing conditions and the work the shipyard is expected to undertake. This enables the shipyard to prepare the job order and to make an accurate estimate of cost. Items required on shipyard work request forms vary according to local procedures. Generally, however, the following information must appear:

1. Name, model, and serial number of equipment
2. Location
3. Work to be accomplished
4. Material to be supplied by ship
5. Publications (instruction book, blueprints) needed
6. Available assistance by ship's force
7. Names of ship's personnel authorized to inspect job at completion

The CSMP (current ships' maintenance projects) may be of great assistance in making out work requests since the CSMP should contain most of the outstanding work required.

Tender Or Repair Ship Requests

Tender or repair ship work requests are submitted as far in advance of the availability period as is possible. They are forwarded to the type commander for approval and assignment to a repair ship or tender. The request forms used by fleets, tenders, or repair ships vary. However, all require certain data, including the following items:

1. Bureau having cognizance of the repair
2. Expenditure account to which work is charged (repairs are charged to the 14,000-series)
3. Group or index number
4. Ship's serial number (the number of the request and year, as 120-61)
5. A brief of the repair work required. This includes a description of the work, materials required, a list of blueprints (if necessary), and sketches as may be required. Don't use the ambiguous term "Overhaul and repair as necessary."
6. The extent to which the ship's force will assist in the work.

A complete tender work request form is shown in figure 13-5.

Remember that work requests should be submitted only for work which is beyond the capacity of the ship's force to perform. A record of all repairs, whether accomplished by a shipyard or tender, must be kept on the current ship's maintenance project.

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REQUEST FOR REPAIR PARTS

NAV. S. AND A. FORM 302

NAME OF ACTIVITY OR SHIP: Langley CVA 111

SAME NUMBER AS 1150 REQUISITION

REQUEST NO.: OPER 254

DEPARTMENT: Operations

DATE: 24 November —

REPAIR PART BOX No.: S 58-1/12

INDICATE REPAIR PARTS BOX NO.

ALLOWANCE LIST: GROUP No.

STOREROOM No.

PAGE No.

ITEM NO.	STOCK NO. OR PART NO.	DESCRIPTION	UNIT	QUANTITY	REPAIR PART LIST NO.	ALLOWANCE LIST LINE NO.
1		Voltage divider	EA	1		
		Resistor R320,				
		Fixed, composition, pigtail,				
		39000 ohms, ±10% ½ watt,				
		insulated				
		Navy Type No. 63360				

ALLOWANCE LIST DATA FILLED IN WHEN APPLICABLE

ABOVE ITEMS TO BE USED ON/WITH: Model RBB Receiver

NAME PLATE DATA

SERIAL NO.: 1220	TYPE NO.: CRV-46147	MODEL NO.: RBB	STYLE
MFR.'S DRAWING NO.	NAVY DRAWING NO.	P. C. NO.	CONTRACT NO.: NOs-73056
HP.	R. P. M.		CFM
VOLTAGE	A. C. OR D. C.		OHMS
PHASE	CYCLE	BORE	STROKE
SIZE	JOB ORDER NO.	CATALOG NO.	SPECIFICATION NO.

NAME PLATE DATA ESSENTIAL TO OBTAIN CORRECT REPAIR PARTS

ADDITIONAL NAME PLATE DATA: Model RBB Receiver manufactured by Radio Corporation of America

OTHER IDENTIFYING INFORMATION

MANUFACTURER: International Resistance Corp.

LATEST ACCEPTABLE DELIVERY DATE: 2 January —

MANUFACTURER'S ADDRESS: Philadelphia, Pa.

SOURCE OF SUPPLY

DRAWN OUT OF REPAIR PARTS BOX BY

UPON RECEIPT NOTIFY

SUBMITTED BY

APPROVED BY HEAD OF DEPARTMENT

INDICATE NAME AND ADDRESS OF MANUFACTURER

PREPARED BY REQUIRING DEPARTMENT HEAD TO ASSIST IN PREPARATION OF REQUISITION FOR REPAIR PARTS

DATE ORDERED | ORDERED FROM | REQUISITION No.

REQUISITIONING INFORMATION TYPED IN BY SUPPLY OFFICE PERSONNEL

U. S. GOVERN... 98-2

Figure 13-4.—Request for repair parts (NavSandA Form 302).

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Ship's Memorandum Work Request

A ship's memorandum work request is an interdepartmental routine request for work requiring assistance by another shipboard department. This form enforces proper channeling of work requests between heads of departments

equipment reports are the responsibility of the electronics material officer. However, you will be called upon to help fill out some of the reports. For example: in the Electronics Performance and Operational Report (NavShips 3878) there are spaces to be filled in calling for maximum detectable radar range and minimum reliable

TENDER WORK REQUEST
DESLANT Form 4710-1 (Rev. 7/53)
File L9-3/S_____

ORIGINAL 11-59 22 September — (DATE)

FROM: Commanding Officer, U. S. S. USS ROBERT F. KELLER (DE-419)

TO. Repair Officer, USS SIERRA

SUBJECT: Work Request ☐ ALT ☐ REP ☐ HULL ☐ MACH ☐ ORD ■ ELEC ☐ RAD

1. The following work beyond the capacity of the ship's force is requested:

SPECIFICATIONS:

(a) AN/SPA-4A, Serial No. 1099
(b) In CIC
(c) Install 500V Rectifiers
(d) Spare parts
(e) Instruction book
(f) Assist as necessary
(g) HELGE, RDC

2. Ship's force will assist as follows:

☐ FURNISH DRAWING
☐ SKETCH
☐ SAMPLES
☐ DAMAGED PARTS
☐ DELIVER AND CALL FOR
■ LABOR

3. DESIRED COMPLETION DATE: 24 September —

J. P. Vernon
J. P. VERNON, LCDR, USN
(SIGNATURE, COMMANDING OFFICER)

W. R. NO.	PRIORITY	COMPLETION DATE	PERCENT COMPLETED 0 | 25 | 50 | 75 | 100	(SIGNATURE-TENDER'S SHOP PO IN C) (DATE)

List material needed when ordered and amounts used on reverse side. List blueprints where essential.

FIRST ENDORSEMENT

From:

To:

Approved: ☐ YES ☐ NO

(Leave blank) For Repair Act.

MAN HOURS

STARTED	COMPLETED
SHOP NO	
SHOP NO.	
SHOP NO.	
SHOP NO.	
TOTAL	

INSPECTED, PASSED, AND RECEIVED

(DATE)

(SIGNATURE) (RANK/RATE)

Figure 13-5.—Tender work request (DesLant Form 4710-1).

and permits setting up priorities of available manpower and facilities. No two ships will use the same type of request, because there is no standard form. The request usually will contain the scope of work with complete specifications and necessary plans, plus the name of the person familiar with the job to be done.

COMPILING REPORTS

So far we have spoken only of logs, records, and publications. Occasionally the Radarman 3 or 2 will assist in making out reports. Most

radar range for a particular radar for a month (see fig. 13-6). Since members of the electronics division normally do not stand watches in CIC, they will not know these ranges. You will be called upon to supply them. A radar performance log kept in CIC, or at the master console, with comments entered from watch to watch, will help to supply this valuable information. The Electronics Maintenance Book contains a sample report and detailed instructions for preparation of the Electronics Performance and Operational Report (NavShips 3878).

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ELECTRONICS PERFORMANCE AND OPERATIONAL REPORT

NAVSHIPS 3878 (REV. 6-52) — *Submit original ONLY to Bureau* — REPORT-SHIPS-192

FROM: U.S.S. LAFFEY (DD-724) (Ship's Name, Type and Hull No.) ATLANTIC (FLEET)

TO: Chief, Bureau of Ships

CLASSIFICATION:

DATE: 1 NOV. 19-

PERIOD OF REPORT: FROM 1 OCT. 19- TO 31 OCT 19-

CHECK EQUIPMENT CATEGORY REPORTED ON: ☐ RADIO ☒ RADAR ☐ SONAR ☐ OTHER

MODEL OR TYPE OF EQUIPMENT: AN/ SPS -6B

SERIAL NUMBER	86					
HOURS OF OPERATION DURING PERIOD OF REPORT	614					
HOURS NOT IN OPERATING CONDITION DURING PERIOD OF REPORT	76					
OVERALL PERFORMANCE POOR 0 - 40% AVERAGE 40 - 70% GOOD 70 - 100%	70 %	%	%	%	%	%
APPLICABLE FIELD CHANGES NOT ACCOMPLISHED TO DATE	NONE					
MAXIMUM RELIABLE RANGE (Radio, countermeasures and infra-red)						
MAXIMUM DETECTABLE RADAR RANGE*	MI 85 E 1	MI E	MI E	MI E	MI E	MI E
MINIMUM RELIABLE RADAR RANGE*	YDS 6000 E 4	YDS E	YDS E	YDS E	YDS E	YDS E
TYPE OF TARGET**	1					
ALTITUDE AT MAXIMUM DETECTABLE RADAR RANGE						
AVERAGE ECHO BOX RING TIME	4990					
AVERAGE VOLTAGE STANDING WAGE RATIO IN RADAR TRANSMISSION LINE	2:1					
MAXIMUM DETECTABLE ECHO SONAR RANGE	YDS	YDS	YDS	YDS	YDS	YDS
MAXIMUM DETECTABLE LISTENING SONAR RANGE	YDS	YDS	YDS	YDS	YDS	YDS
MAXIMUM SOUNDING SONAR	FMS	FMS	FMS	FMS	FMS	FMS

INSTRUCTIONS

* *Report Signal to Noise Ratio in "E" Units.*

** *Indicate No. for type*

1. *Large plane*
2. *Small plane*
3. *Group of planes*
4. *Ship*
5. *Submarine*
6. *Buoy*
7. *Rain squall*
8. *Blimp*
9. *Land*
10. *Iceberg*
11. *Misc. small targets*

NO FORWARDING LETTER IS REQUIRED

GENERAL REMARKS (Report Ambient and Equipment Temperature in DEGREES if undue heating occurs, interference encountered, voltage fluctuations, major failures, new applications, unusual propagation and oceanographic conditions, inadequacy of test equipment aboard, explanation of unusual performance of operational difficulties, etc. For communication equipment list the frequency and power used together with time of day.)

SIGNATURE: J. P. Federko
J. P. FEDERKO CDR., USN

CLASSIFICATION:

E-40882

Figure 13-6.—Electronics performance and operational report (NavShips 3878).

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ELECTRONIC FAILURE REPORT

Another type of report you may be called upon to help fill out is the electronic failure report. The Bureau of Ships must be informed of all failures and deficiencies observed in electronic equipment. This report (1) provides the Bureau with a comprehensive presentation of the overall performance of electronic equipment; and (2) forms the basis on which to procure maintenance parts. The report is made on Electronic Failure Report (DD Form 787). (See fig. 13-7.) The operator or technician detecting the failure should fill in the report.

A separate report is made for each failure. When the model or type of equipment is indicated, ensure that all significant nomenclature, letters, and digits are included. Be sure the entry of why the failure occurred is accurate and complete. Explanatory comments should appear in the "Remarks" portion of the form. As a final check, and whenever in doubt regarding the correct method of filling in a specific section of the form, break out the interleaved instructions included with each pad of failure reports.

Keep in mind that the Electronic Failure Report is not a requisition form. Replacement parts must be requisitioned separately.

A good practice is to log the failure report in the radar performance log also, then if the report slip gets lost you will have a record of the trouble.

OPERATIONAL REPORTS

The operational reports required by the Chief of Naval Operations and fleet commanders are listed in NWIP 10-1. This publication gives the frequency, format, and time to submit reports. You will be required to help the CIC officer make out these reports. So as to save time and be accurate, check NWIP 10-1 for the reports that are required and the information CIC must furnish for them. For each operation, consult the Reports Annex to the Op Order for the specific reports required.

REPORT THE FAILURE OF ONLY ONE PART OR TUBE ON THIS FORM

1. REPORT NO.	2. REPORTING ACTIVITY	3. REPAIRED OR REPORTED BY (NAME)	4. DATE OF FAILURE
	U.S.S. LAFFEY	D. UPTON ETR 3	3/23/—

5. EQUIPMENT INSTALLED IN (TYPE AND NO.)	6. TIME METER READING OR INSTALLATION LOG TIME	7. WAS MISSION ABORTED?	8. OPERATIONAL CONDITION
DD 724		☐ YES ☐ NO	

	9. MODEL DESIGNATION AND MOD. NO.	10. SERIAL NO.	11. CONTRACTOR	12. CONTRACT OR ORDER NO.
EQUIPMENT	AN/SPS-10	147	SYLVANIA ELECTRIC	NOBSR 52166
COMPONENT (MAJOR UNIT)	13. MODEL DESIGNATION AND MOD. NO.	14. SERIAL NO.	15. CONTRACTOR	16. CONTRACT OR ORDER NO.
	AS-615 ANTENNA ASSEMBLY	30	SYLVANIA ELECTRIC	NOBSR 52166
ASSEMBLY OR SUBASSEMBLY	17. ASSEMBLY AND MOD. NO.	18. SERIAL NO.	19. MANUFACTURER	20. (LEAVE BLANK)
	—	—	—	

PART DATA	21. PART NAME OR TUBE TYPE	22. STOCK NO. (FAILED ITEM)	23. PART REF. DESIG. (V-101, R-101, ETC.)	24. REPAIR TIME (MAN-HOURS)
	MOTOR	NM-5920-235-2245	B-801	2
	25. HOURS IN SERVICE	26. MANUFACTURER OF FAILED PART	27. SERIAL NO.	28. WAS REPLACEMENT PART AVAILABLE LOCALLY
		GEN MOTOR COMPANY	223	☑ YES ☐ NO

29. FIRST INDICATION OF TROUBLE		30. CHECK TYPE(S) OF TUBE OR PART FAILURE								31. CAUSE OF FAILURE	
1	☑ INOPERATIVE	007	☐ ARCING	001	☐ GASSY	790	☐ OUT OF ADJUST.	2	☐ FAULTY PACKAGING		
2	☐ INTERMITTENT	710	☑ BEARING FAILURE	300	☐ GROUNDED	006	☐ SHORTED	5	☐ MISHANDLING		
3	☐ LOW PERFORMANCE	760	☐ BENT	380	☐ LEAKAGE	770	☐ SLIP RING OR COMMUTATOR FAILURE	6	☐ INSPECTION OR TEST		
4	☐ NOISY	040	☐ BINDING	730	☐ LOOSE			1	☑ NORMAL OPERATION		
5	☐ OFF FREQUENCY	070	☐ BROKEN	004	☐ LOW GM OR EMISSION	018	☐ TESTED OK DID NOT WORK	3	☐ STORAGE		
6	☐ OUT OF ADJUSTMENT	720	☐ BRUSH FAILURE	750	☐ MISSING			7	☐ ASSOCIATED FAILURE-EXPLAIN		
7	☐ OVERHEATING	080	☐ BURNED OUT	008	☐ NOISY	020	☐ WORN EXCESSIVELY	4	☐ OTHER		
8	☐ UNSTABLE	130	☐ CHANGED VALUE	450	☐ OPEN		☐ SEE INSIDE FLAP FOR ADDITIONAL CODES	32. WAS THE PART REPLACED DURING PREVENTIVE MAINTENANCE? ☐ YES ☐ NO			
9	☐ OTHER	170	☐ CORRODED	099	☐ OTHER						

33. REMARKS (Continue on reverse side if necessary)

DD (1 AUG 54) 787 — ELECTRONIC FAILURE REPORT — A15907

Figure 13-7.—Electronic failure report (DD Form 787).

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COMPETITIVE EXERCISE REPORTS

FXP's 1 and 3 list the training exercises required of surface ships. Chapter 6 of FXP 3 contains the CIC, communication, ECM, and air defense exercises, together with evaluation sheets. CNO requires a copy of all competitive CIC exercises. You will have to help the CIC officer observe and grade these exercises on other ships, as well as drill your own CIC group in the exercises required for your ship. You must be familiar with the instructions for observing and marking these exercises.

QUIZ

1. Name the three classes of logs used in the CIC.
2. What is the purpose of logs?
3. Who is responsible for maintaining logs in CIC?
4. Name the minimum logs considered as adequate for record keeping in CIC.
5. As a leading petty officer, what is your responsibility concerning the assignment of performance evaluation grades?
6. (a) What is NavPers Form 760 (RD)?
   (b) How many parts?
   (c) What do they contain?
   (d) Where are the instructions for maintaining the form?
7. What publications give detailed technical instructions to supplement the doctrine found in the NWP's?
8. What publication does a Radarman have cause to use more frequently than any other?
9. Who should make out an Electronic Failure Report?
10. Where are the CIC training exercises listed?

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CHAPTER 14

SURFACE PLOTTING

IMPORTANCE OF PLOTS

The CIC team is responsible for keeping command informed of the location, identity, and movement of friendly and/or enemy aircraft and surface ships within the area.

By means of internal and external communication systems (primarily by sound-powered telephone and radiotelephone), CIC collects tactical data from the following major sources: radar, sonar, radio, visual communications, and publications (operation plans, orders, etc.).

Since a CIC under battle conditions handles many contact and amplifying reports, the tactical information must be available to the evaluator in such a way that each report can be seen in its true relation to every other report and to the individual ships. Accurate plots have been found to be the best method of utilizing the information received in CIC. Regardless of the equipment used for obtaining the plot, the plot must transpose a series of bearings, ranges, and other collected data into understandable pictures that tell the story of events taking place in the area.

HOW CIC KEEPS TRACK OF THE SURFACE SITUATION

As you recall, in chapter 3 we discussed the five functions of CIC. Collecting information from all available sources is the first function of CIC. This information is of little use, however, unless it is displayed so that each part can be evaluated in relation to the whole.

The second function of CIC is the visual display of all information. Adequate display demands the special attention of Radarmen so that such key personnel as the evaluator, CIC officer, CIC watch officer, air controllers, and command personnel can perform their duties well. These key personnel are completely dependent on the plotters for the quick and accurate display of the required information in a neat, readable form.

You will find that one of the most important aspects of your job as a Radarman is plotting and maintaining the various displays aboard your ship. Even with the most modern equipment, a Radarman must still be familiar with the methods of plotting. This means that a Radarman must know the techniques to be employed, the symbols and abbreviations required, the equipment used, and the types of displays that will produce the desired accuracy in the portrayal of the sequence of events.

YOUR JOB IN KEEPING TRACK OF THE SURFACE SITUATION

Chapter 3 also dealt with some of the displays used in CIC, their purpose, and certain information to be shown thereon. Now, let us examine a few of the principal plots and status boards applicable to the surface situation.

It is essential that all members of the CIC team be familiar with their duties and responsibilities. Each person should be able to man any position and perform any function. During general quarters, personnel usually are assigned to positions where they perform best in order to have a more effective team during combat. For the purpose of familiarization and training, they are rotated at the various stations during normal cruising watches. Depending on the type of ship, the number of men in CIC varies; for example, in a small ship one person might be required to perform a job that two or three would handle in a larger organization.

A TYPICAL SITUATION

Figure 14-1 shows how the CIC surface personnel work as a team, and illustrates the orderly flow of information to all who need to know. It shows how the CIC watch officer is able to make recommendations to command, based on the plots and displays the Radarman maintains.

To see how the team works in a typical situation, imagine that you are standing a watch in CIC on a destroyer. Your ship and three other

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RAID	BRG	RNG	TIME	CUS	SP	CPA	TIME OF CPA	REMARKS
A	030	18,000	1800					I-S
A	037	17,000	1801					
A	045	16,000	1802					
A	052	15,000	1803	143	32	17/3000	1805	
A	060	14,000						

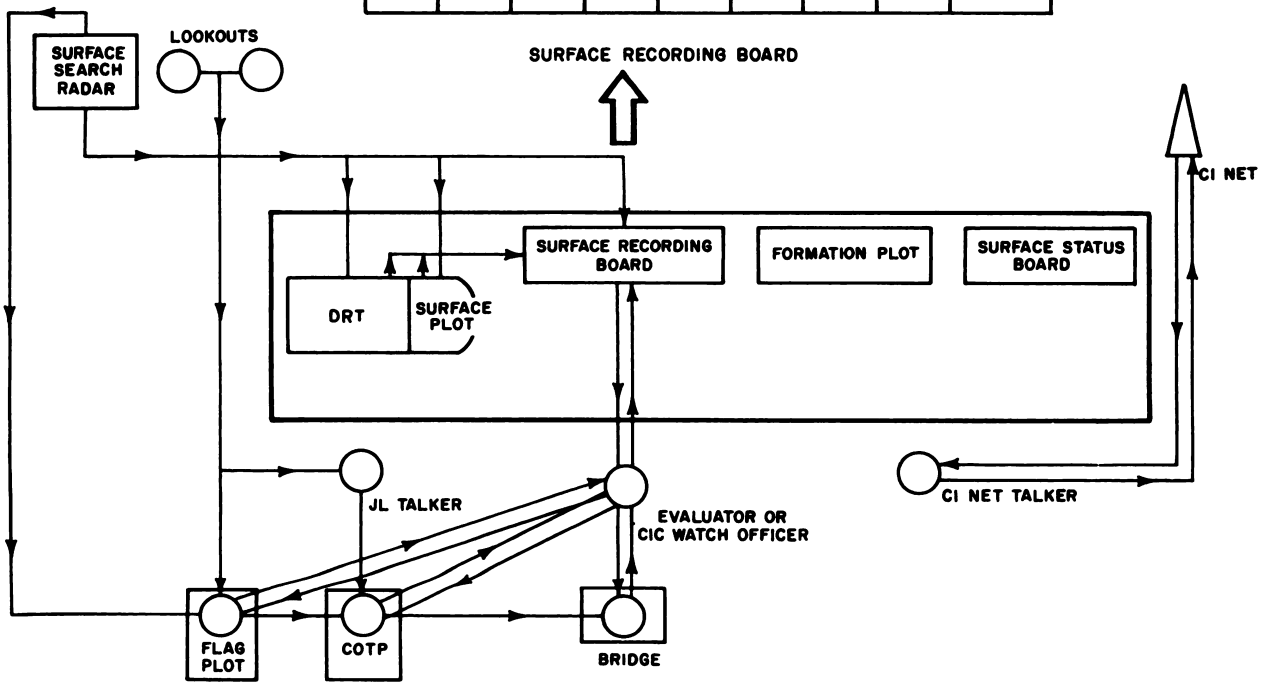

Figure 14-1.—Orderly flow of information from CIC.

destroyers are escorting a carrier. As you steam along ahead of the carrier, the sonar operator on your ship and in the other destroyers is searching for submerged submarines, while the radar operators search for objects on the surface of the water and in the air.

At time 1800, the radar operator sees a pip on his radarscope and makes his report to CIC: SURFACE CONTACT—030—18,000—CLOSING—COMPOSITION ONE SMALL. Immediately the CIC watch officer passes the contact report to the OOD on the bridge, and the OOD notifies the Captain. If your ship has a commanding officer's tactical plot (COTP) and flag plot, both should be notified at the same time.

CI Net Talker

The CI net talker promptly sends the appropriate message on the CI net to all ships in company. The OTC is responsible for the defense of the force against air attack, and for surface action. He may delegate control of air defense to the air defense ship, which may further delegate the control of air warning radar and air raid reporting to an air raid reporting control ship. The OTC may also delegate control of surface warning radar and surface (and submarine) raid reporting to a surface raid reporting control ship. The surface raid reporting control ship acknowledges the CI net talker's message and tells the formation of group to designate the Skunk (Alfa, Bravo, Charlie, etc.), and also tells

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your ship or another to report. Since all ships in company are tuned in on the CI net, they know the designation and location of the contact. The CI net talker then observes the surface recording board and makes appropriate reports every 3 minutes. The CI net talker can report directly from the board. Plotters on each ship keep track of the contact on their plotting boards, using the CI net reports until their radar operators can detect the contact.

Aboard your ship, the geographic plotter (DRT), surface plotter, surface summary plotter in COTP, and the surface summary plotter in flag plot all receive bearings and ranges from the surface-search radar via the 22JS phone circuit. They apply the data in tracking surface contacts on the DRT and the polar coordinate charts. A recorder on the 22JS phone circuit enters contact ranges and bearings on a surface recording board similar to the one in figure 14-1. He records each range and bearing as it is received over the phone from the radar operator; the time of each report also is entered. This record serves to backstop the plotters. If they missed the range, bearing, or time of a report, they can refer to the recorder board. This information also aids the evaluator or CIC watch officer in making reports to command.

DRT Operator

The DRT operator plots the contact on first report. From later reports he determines the contact's course and speed. He then reports his solution over the phone circuit.

Surface Recorder

The surface recorder writes any additional information in the applicable columns on the surface recording board.

Surface Summary Plotters

Inasmuch as the surface summary plotters in COTP and flag plot are on the same circuit, they receive the course and speed of the contact computed by the DRT operator and sent over the phones. The summary plotters show this course and speed in a rectangular-shaped box next to the time of computation. By observing the plotting boards, officers in flag plot and COTP are notified of the contact's course, speed, and position.

Surface Plotter

The surface plotter also plots the successive positions of the contact as reported by the radar operator and determines the contact's closest point of approach (CPA) and the time the contact will reach that point. The CPA and time are sent over the phone circuit. Surface summary plotters in flag plot and COTP record this CPA data on their plots. Duties of the surface plotter also include plotting and recommending the following to the CIC watch officer:

1. Plotting low-altitude air contacts and ensuring that the evaluator and/or CIC watch officer are notified immediately of initial plot.
2. Displaying target designation sectors of all ships in the formation for antiaircraft (AA) coordination purposes.
3. Making recommendations to OOD, via the CIC watch officer, of course and speed own ship must take to get on station when a change of station is ordered by OTC.
4. Furnishing relative bearings to JL talker to relay to lookouts for identification of surface or low-flying aircraft.

JL Talker in CIC

With close coordination between the CIC JL phone talker and the lookouts, they often can identify an object. As radar contacts approach visual range, the lookouts should be cautioned to expect an object on the appropriate bearing. When a target gets within visual range, the lookout makes the identification, the JL talker relays the identification to the CIC watch officer, the surface recorder is notified and, in turn, indicates the target's identity in the remarks column of the surface recording board. The plotters label the plot with the identification and keep track of it until the surface raid reporting control ship orders you to scrub the contact.

CIC Watch Officer

From the foregoing description and the illustration, you can see how CIC works as a team to keep track of the surface situation.

Under the control of the CIC watch officer, the entire surface picture is displayed. From his station he can observe the situation. His previous knowledge of the operation order, operation plan, and intelligence reports enables him to evaluate the situation and keep command

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informed. In this manner, the essential information on a new contact, which the OOD always requires, is supplied quickly and efficiently. In some ships a JA talker in CIC passes information to the bridge.

As the minutes pass, additional plots are obtained. They permit more accurate solutions, which also are relayed to the bridge as warranted by the tactical situation.

When entering or leaving port, or steaming in fleet operating areas, the surface plot can become overloaded and confused due to the large number of contacts. The CIC watch officer must supervise closely the plotting of contacts, designating the ones to concentrate on and those to scrub.

INFORMATION TO THE BRIDGE

Information on new contacts should be passed to the CICWO who evaluates it and makes recommendations to the OOD on the bridge as a matter of routine. Observance of the following suggestions will help eliminate the "Wait" so often used in replying to queries from the OOD.

1. Immediately on detection, pass the range and bearing of all new contacts to the bridge.
2. Give the raid designation, as Skunk, Alfa, Bravo, Charlie, etc.
3. Ascertain identification, either with proper IFF mode response, or on the basis of an evaluation of other information available.
4. Give composition of contact, for example, single large ship, formation of small ships, etc.
5. Give estimate of true course and speed of contact.
6. Concerning the point and time of closest approach, give a preliminary estimate after three or four plots, followed by more accurate information; also whether on or near collision course.
7. Give an evaluation of contact by weighing all available information and past movements, determing its future movements and intentions, and recommending an appropriate course of action.

If the DRT plotter and surface plotter rapidly and accurately furnish the surface recorder the information to be displayed, the CIC watch officer or his talker, by watching the surface recorder board, can give the data to the OOD immediately.

BASIC PLOTTING DEFINITIONS AND TERMINOLOGY

To maintain plots properly plotters must be thoroughly familiar with the basic procedures for plotting bearings, and the terminology used in communicating with commands. As an example, the contact reported at bearing 030 and range of 18,000 yards might be a submarine on the surface, a friendly merchant vessel, or an enemy surface unit. Since the OTC is responsible for the defense of the force against air attack and for surface action, he decides to detach your ship to investigate the contact.

CIC receives the following from the Captain: "What is the course that will take me to a position 2000 yards west of the contact, and how long will it take to get there using a speed of 30 knots?"

These are problems for the surface plotter. The Captain must be given the correct answers quickly; there is no time to waste, and no excuse for an incorrect solution. When the Captain requests a course to a certain position, he must have the information in seconds, not minutes. Five minutes later would be too late, for at 30 knots your ship would be traveling at half a mile a minute. Various methods are used for finding the answers: the DRT, surface plot, maneuvering board, or you can work out the solutions on the face of a PPI-scope. Normally the surface plot is used.

Regardless of the method selected, you must know all about the maneuvering board. Chapter 16 of this text goes into the details of solving maneuvering board problems and other kinds of problems. First, though, you must learn the basic procedures for plotting bearings and the terminology peculiar to communications with command.

Consider what might happen if the Captain had requested the information in the following manner: "I want a course to take our ship to a position 2000 yards from the target at a target angle of 300°. We will use a speed of 30 knots to make the maneuver."

His order might have been in this form: "I want a course to take our ship to a position 2000 yards at a bearing of 270° true from the contact." Instead, he asked for a course to take the ship to a position 2000 yards west of the contact.

Obviously, if there is more than one system for indicating the direction of any object from another, there is danger of confusion unless you clearly understand exactly what the Captain

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wants. Thus, it is easy to see why it is so essential to know the exact meaning of both TRUE and RELATIVE bearings when solving any maneuvering problem on the DRT, surface plot, maneuvering board, or PPI-scope. You also must have a thorough knowledge of the methods of converting true bearings to relative bearings, and vice versa.

TRUE BEARING

As you know, true bearing is the angular measurement between true north and the line of bearing to an object. This is always measured clockwise from north. All bearings, written or spoken, are considered to be true bearings unless stated otherwise. True bearings are plotted directly on the DRT, surface plot, and maneuvering board exactly as received from the radar operator. Relative bearings, however, must be converted to true bearings prior to plotting.

RELATIVE BEARING

Relative bearing is the angular measurement between own ship's head at that moment and the line of bearing to an object. This is always measured clockwise from own ship's head to the line of bearing. Other ways of expressing relative bearing are by such terms as the following (see also fig. 14-2):

Dead ahead—Directly ahead. An exact relative bearing of 000°.

Broad on bow (starboard or port)—An exact relative bearing of 045° or 315°.

Broad on beam (starboard or port)—An exact relative bearing of 090° or 270°.

Broad on quarter (starboard or port)—An exact relative bearing of 135° or 225°.

Astern—Toward the rear or after end of a ship or formation. An exact relative bearing of 180°.

For any of these terms, own ship's course must be known to determine true bearing from your ship; the target's course must be known, to determine true bearing from the target. Following are formulas for converting bearings.

1. True bearing of an object equals relative bearing of the object plus ship's head (course of your ship). (TB=RB+SH.) If the answer obtained exceeds 360°, subtract 360°.
2. Relative bearing of an object equals true bearing of the object minus ship's head. (RB=TB-SH.) If SH is greater than TB add 360° to TB and subtract SH.

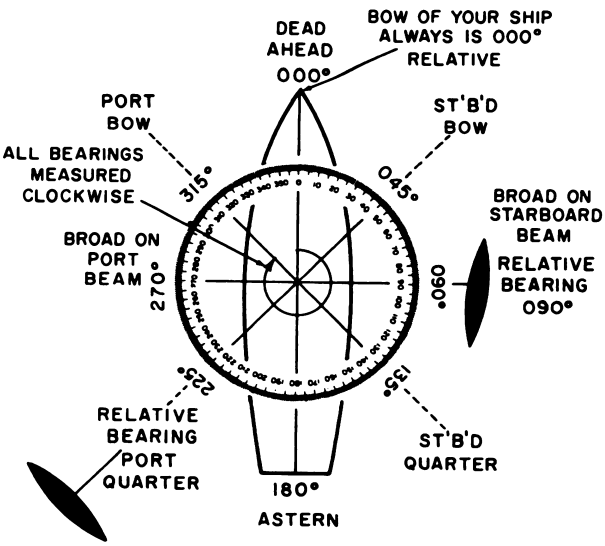

Figure 14-2.—Relative bearings about a ship.

3. Course of your ship equals true bearing of an object minus the relative bearing of the object. (SH=TB-RB.) If RB is greater than TB add 360° to TB and subtract RB.

Study the formulas carefully. The quiz at the end of the chapter will give you some practice in bearing conversion.

RECIPROCAL BEARING

A reciprocal bearing is a bearing which is 180°, plus or minus, from that indicated. For example, the reciprocal of 090° is 090° + 180° = 270°; the reciprocal of 315° is 315° - 180° = 135°.

Suppose a ship bears 100° from own ship, then the bearing of own ship from the other ship is the reciprocal of 100°, or 280°.

TARGET ANGLE

Target angle is the relative bearing of your ship from the target. Imagine yourself aboard the target ship, and measure the relative bearing to your ship. This is the angle measured clockwise from the head of the target ship to the line of bearing between the target and your ship. Target angle is used for the most part to determine which and how many guns the target will be able to bring to bear on your ship.

In CIC, because you cannot see the target except as a pip on your scope, it is convenient to use the formula: Target angle equals true

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bearing of the target from your ship plus 180° minus the course of the target. Assume that the true bearing of a target is 100°. Add this to 180°. Now subtract the target's course, for example 340°. You can see that you cannot subtract 340° from 280°, so another rule applies here: If target course is greater than the reciprocal of true bearing, add 360° to target true bearing before subtracting target course. The answer is 300° (R).

SURFACE PLOTS AND STATUS BOARDS

As a Radarman during the course of a 4-hour watch, you may be rotated at 30-minute intervals between any or such different positions as surface-search radar operator, DRT plotter, surface plotter, sound-powered and radiotelephone talker, radio net recorder, air-search radar operator, summary plotter, tote board, ECM operator, and surface recorder board keeper.

Listed are some of the plots and status boards of primary importance to the surface picture, and some of the information which may be found on them. No attempt is made to prescribe the exact format of status boards; the particular mission of the ship, available space, and arrangement of equipment will greatly influence layouts. These surface plots and status boards are taken up in subsequent paragraphs in the following order:

1. Geographic plot (DRT).
2. Surface plot.
3. Surface summary plot.
4. Formation diagram plot.
5. Maneuvering board.
6. Surface status board.
7. Communication status board.
8. Electronic status board.
9. RADCM status board.
10. Strategic and tactical charts.

GEOGRAPHIC PLOT

The geographic plot shows true movement of ships and aircraft, whereas polar plots show relative movement. For all practical purposes, however, the polar plot shows the true movement of aircraft, since a ship's movement compared with a plane's is so small that it can be disregarded. Owing to the greater capacity of the polar plot to handle many more contacts than the geographic plot, its use is more general in CIC than the geographic plot. However, if a detailed display is desired, showing the true relationship between ships, planes, and land, the geographic plot is better. Thus the DRT is used mostly when radar piloting in restricted waters, conducting naval gunfire support, torpedo attack control, man overboard, and antisubmarine operations. For a discussion of the DRT see chapter 17.

SURFACE PLOT

The surface plot is one of the most important plots maintained in CIC. It was born of necessity during World War II. Early in that war, friendly ships were fired on and even sunk because the ships involved were unable to keep track of all friendly ships within range. There were cases where Nazi submarines surfaced at night within allied formations and disposed of shipping with relative immunity. Their success with such bold tactics was aided by the lack of a rapid, accurate method of determining the proper stationing of ships. Consequently, there was no way to identify every ship quickly on the radar.

The surface plot, when properly maintained, eliminates the causes of such confused pictures by facilitating continuous identification of other vessels.

The surface plot is a comprehensive, relative display of the positions and tracks of friendly, enemy, and unidentified surface and subsurface targets, of geographical points, and of other data required for an understanding of the complete surface picture. Like the PPI-scope, the surface plot is kept in terms of polar coordinates (ranges and bearings) on a maneuvering board, VG repeater, or any other plotting surface.

Most ships use the horizontal type of plotting board shown in figures 14-3 and 14-4. This type is usually located adjacent to the DRT. In some ships, because of available space, the one in figure 14-4 may be mounted vertically.

The surface plot has many important uses. It is in fact a sort of "answer board" from which can be extracted much of the information that the OOD on the bridge and personnel at other stations find necessary. This holds true whether steaming singly or in formation, whether during condition watches, special sea and anchor details, or at GQ. The surface plot indicates the position of all ships in the formation. It provides the bearing and distance to the guide ship or other units, the closest point of approach of approaching ships, and delineates safe firing arcs. It also aids conversion plotting, and is

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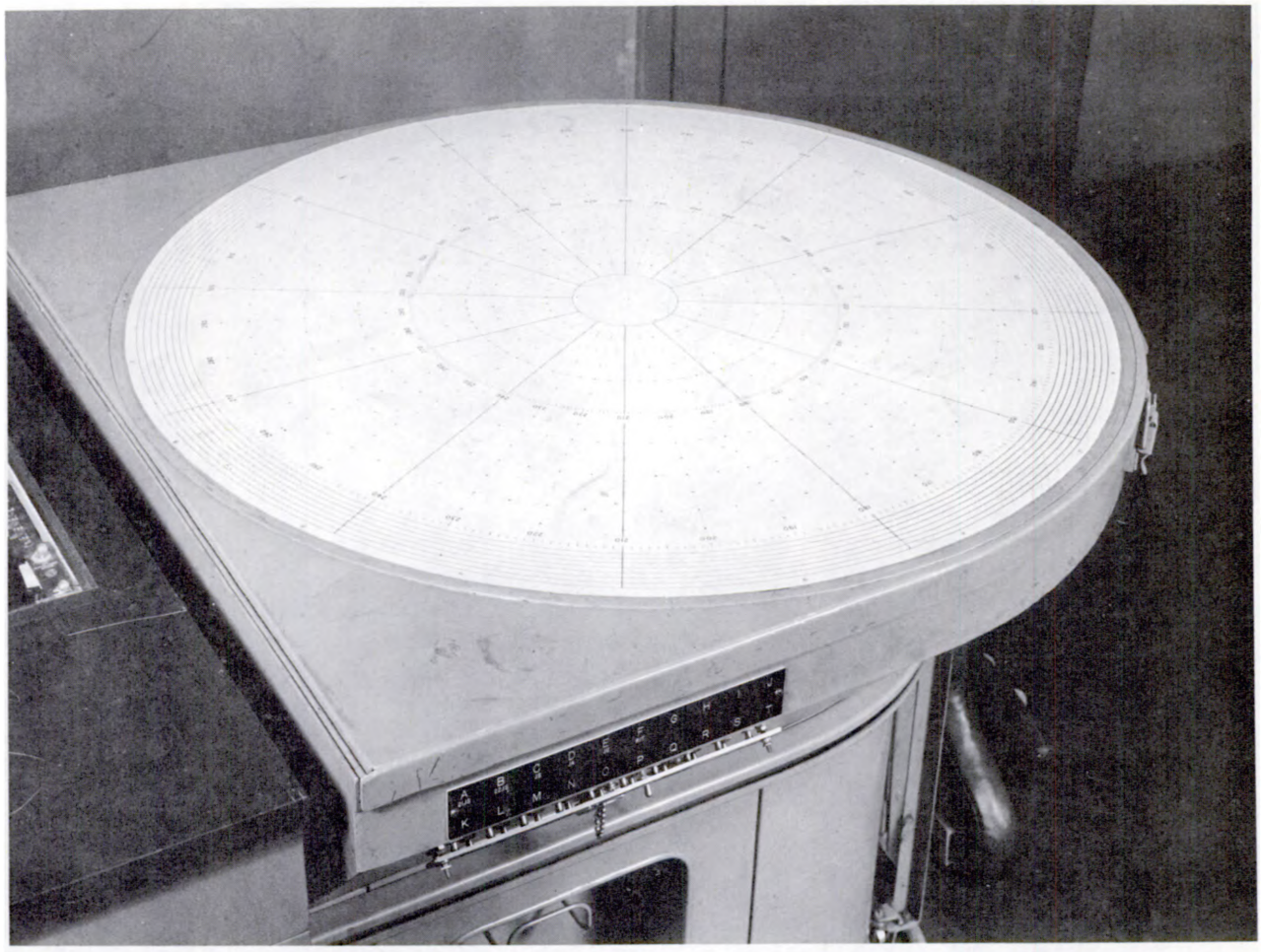

Figure 14-3.—Horizontal type of plotting board.

used as a maneuvering board. By having one scale for own formation of ships and another for long-range information, the surface plot can be utilized as an AA coordination plot, as an A/S attack plot, or for target designation and acquisition.

Surface Plot Scale Requirements

The best scale for use with the surface plot depends upon the tactical situation and the mission of the ship. For most situations, a scale should be chosen which enables all contacts within the maximum range of surface-search equipment to be plotted. Ordinarily a radius of 25 miles will serve best. When ranges greater than this are obtained—as is the case with a ship carrying a height-finding radar capable of surface ranges of 30 miles or more—such long-range contacts are usually plotted on the air summary plot until they close to 25 miles.

The 36-inch horizontal type of plotting board previously shown in figure 14-3 has eight range circles, while the 24-inch type in figure 14-4, that can be mounted vertically or horizontally, has only five. For simplification and ease in reading range on the board, our discussions and illustrations in maintaining the surface plot will use a maneuvering board which has ten range circles.

Occasionally it becomes necessary to use two varying scales on the surface plot at the same time, one for radar contacts and the other for the formation. This is especially true when

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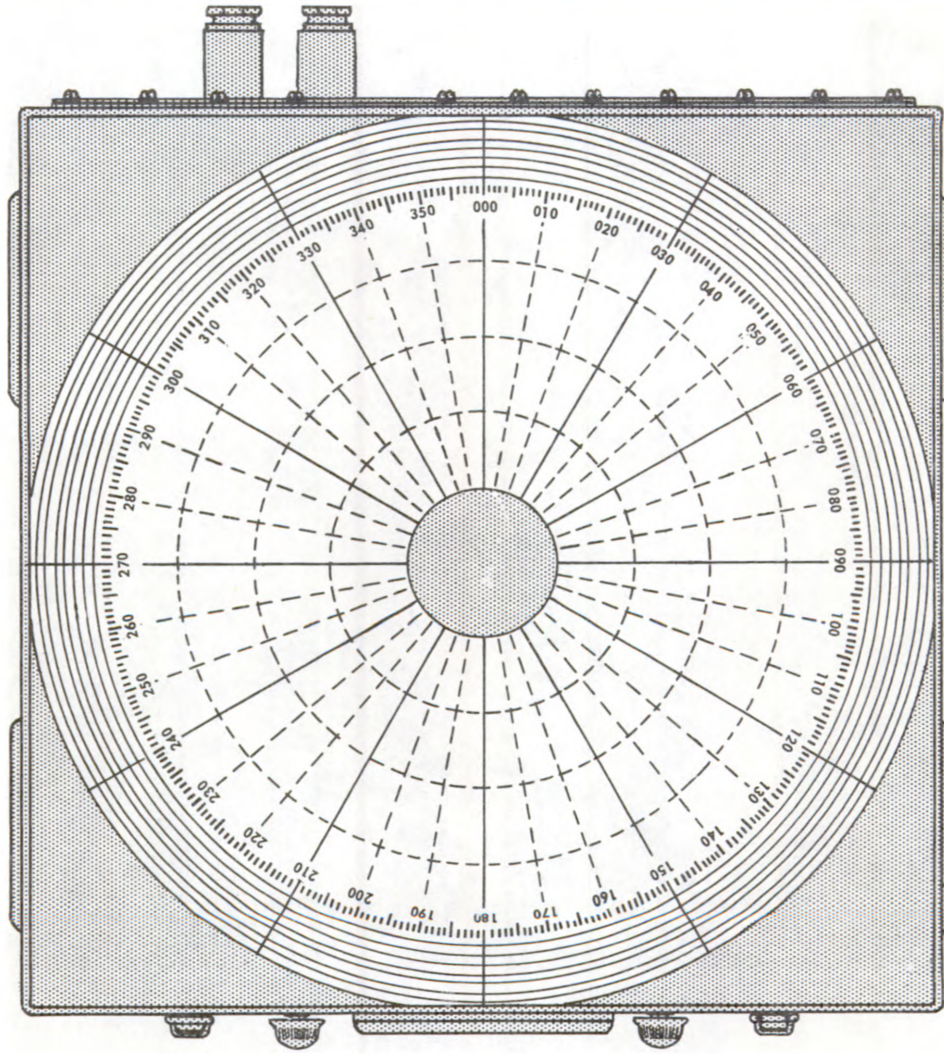

Figure 14-4.—Summary plotting board.

ships in the formation are stationed approximately 1000 or 2000 yards apart, because the plots would be so close together as to be ineffective. In order to have two scales on the same plotting board, most ships employ a color scheme whereby different colors designate different range scales. Colors most often used on certain types of horizontal plots are red for contacts and black for ships in the formation. The vertical type may use red for contacts and yellow for ships in formation. Figure 14-5 illustrates a section of a typical surface plot during a routine watch. It is set up to eliminate delay in arriving at the most important considerations regarding a new contact. The scale is displayed prominently in the lower left corner of the plot so that ranges can be read by the CIC officer or evaluator, even from a distance. Own ship's course and speed are plotted.

Avoid using uneven scales on the surface plot, such as 1.5 knots or 1600 yards per circle. This adjustment of scales, commensurate with the speed and distances, yields solutions accurate to a degree or two, and half a knot. Such accuracy can be expected when working problems in a classroom or in a CIC mockup having ample space and ideal working conditions. But in a shipboard CIC, where the working space is limited, it's another story. Accuracy suffers if you have to solve a problem when someone bumps your elbow while you are thumbing through a signal book or a tactical publication with one

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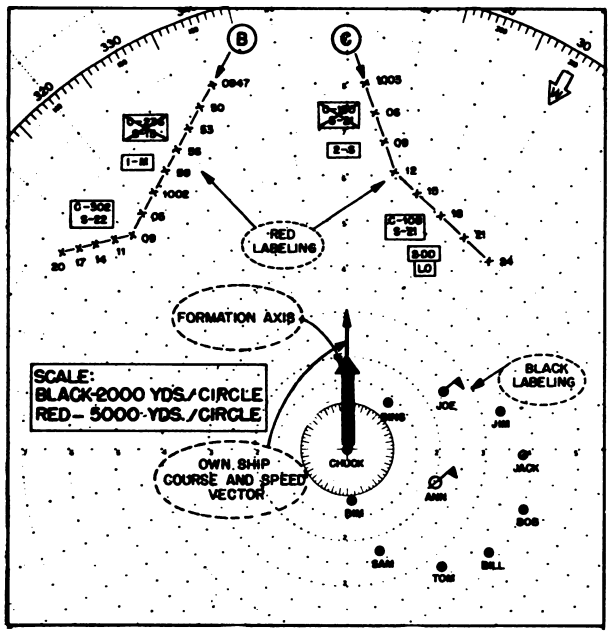

Figure 14-5.—Surface plot.

hand and adjusting a pair of dividers with the other. Furthermore, the plotting surface is not drawn to this type of accuracy. All in all, different scales in plotting can result in general confusion and also inaccuracies. For example, if the CIC watch officer or other personnel desire to check your solution when you are using varying scales, consultation—which otherwise should be unnecessary—is required.

For greater accuracy in working solutions on a polar coordinate plotting surface, the standard maneuvering board should be used.

Symbols Used on Surface Plot

Most information appearing on the surface plot comes from the radars. The DRT operator, ship's lookouts, and radio circuits provide additional information.

Notice in figure 14-5 that the contacts' positions are plotted with a small letter x. This identifies the contact as a skunk or unidentified surface contact. Friendly contacts are shown by a circled dot. The source of each plot should be indicated. Thus, (LO) alongside the track is for a lookout report. A radio report may be plotted in a different colored pencil (perhaps yellow), using standard plotting symbols. These symbols are the same as those on surface plots, surface summary plots, DRT, and formation diagram plots. They are covered in chapter 17 of this text. So that you will have a better understanding of how to maintain the surface plot properly, a few additional symbols are shown in figure 14-6.

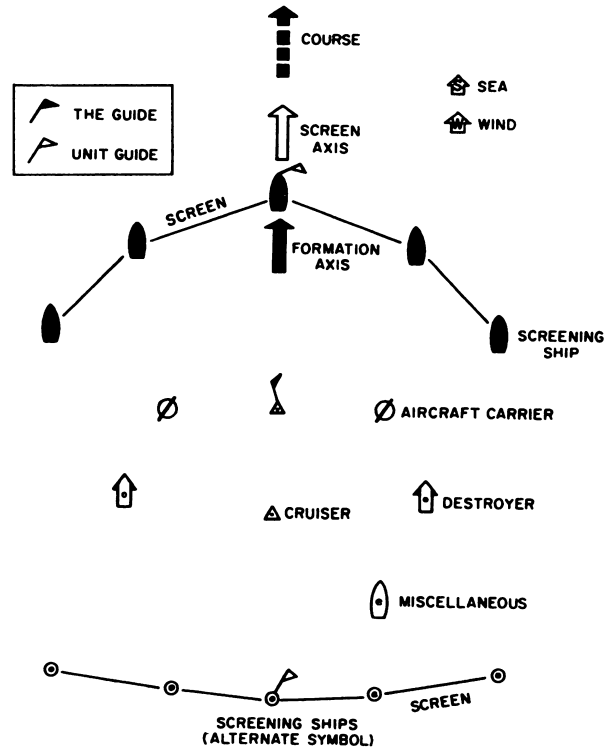

Figure 14-6.—Standard plotting symbols.

Compare the symbols identifying the formation in figure 14-5 with the ones shown in figure 14-6.

By reference to the formation diagram, we obtained the bearing and range of every other ship from our own ship and plotted the positions of the surface plot. Each position is labeled with the radio call, and guides are identified. Also shown are the formation axis, screen axis, course and speed, direction from which the wind is blowing, and the velocity.

Many CIC officers require that only the station letter and/or number be placed adjacent to the plots. In this case the station assignments are placed on the surface status board. This is done especially when a large formation is present and there is little space to write the ship's call sign next to the plots. Symbols on the plot identify the type of ship. The surface

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summary plot always shows the radio call sign and the station number next to the plots.

Plotting Procedure

The radar operator picks up a contact on the surface-search radar, and reports to you by phone: SURFACE CONTACT—030—18,000—CLOSING—COMPOSITION ONE SMALL. You will plot the progress of the contact on the surface plot.

The procedure for maintaining the surface summary plot is identical except more information is plotted. Because the surface recording board is usually next to the surface plot, it is not necessary to place the course, speed, and CPA information next to the track. If you must display all information, however, here is how it is done:

The range on the surface radar is 50,000 yards. Therefore, you most likely would use a distance between rings equal to 5000 yards if using a 10-circle plotting surface (as in our case), unless engaged in an exercise designating another scale.

You must keep close check on the time. The time is 1800. Your first move is to plot the skunk symbol (the small x) at the correct range and bearing, then the time, using four digits for this first plot.

The first report at time 1800 places the target at the intersection of bearing 030° and the range marker of 18,000 yards. (On your scale, a distance of 18,000 yards is 18,000 divided by 5000 or 3.6 rings from the center.) To plot this point, follow the 030° bearing line until it crosses the 3.6 range circle, and indicate the position with the small x. (See fig. 14-7.)

Without loss of motion, draw the RAID DESIGNATION CIRCLE, which is a circle placed near the first plot. This circle, the largest symbol on the board, is about the size of a half dollar on the standard plotting board. It is important that the raid designation circle be plotted immediately after plotting the first contact report, to draw attention to the skunk symbol itself. This symbol is relatively small, and could very easily be overlooked by the CIC watch officer.

When possible, the direction of movement of a contact at this initial plot is indicated by an arrow. In this instance the contact was reported as CLOSING; therefore, the arrow points toward the center of the board. The arrow is joined to the raid designation circle.

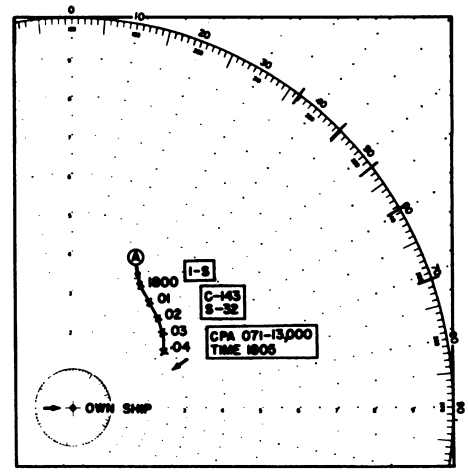

Figure 14-7.—Surface plotting procedure.

Finally, and without delay, plot the information on the size of the skunk, placing it in a rectangular box along the skunk track. This box should be close enough to the skunk symbol so that anyone interpreting the plot will know that the information was given at the same time the symbol was plotted.

Two abbreviations that suggest general size of a raid are: L for large ship (preceded by estimated number), and S for small ship (preceded by estimated number). Using our illustration ONE SMALL, the information that goes in this box is 1S, the abbreviation for "one small." The other reports that you receive are the following:

Time	Bearing	Range
1801	037	17,000
02	045	16,000
03	052	15,000
04	060	14,000

Again plot the skunk symbol at the correct range and bearing with the correct time. The second report locates the contact at the intersection of the bearing line 037°. Seventeen thousand divided by 5000 equals 3.4, the range circle to be used. Because the first time was 1800, the time on this plot might be 01. Remember, in timing, until the start of a new hour, use only two digits after you start developing a track. A four digit time is also used on a new or subsequent hour.

Analyzing this new plot, you note that the ship has traveled approximately 2000 yards in 1 minute, suggesting this is the same contact picked up a minute earlier. Accordingly, connect

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this symbol to the previous plot with a straight line. For neatness and readability, leave space between the plots and the ends of the line.

By this time the report should be made by radiotelephone to the OTC who will designate the skunk. In our illustration the OTC has designated it raid ALFA. This is recorded by placing the letter A in the raid designation circle.

Notice in figure 14-7 the plotting of the next position is located at the intersection of the 045° bearing line, and the 3.2 range circle. The next report locates the target at bearing 052° and three range circles out. All other reports are plotted in a like manner.

A minimum of three plots is necessary to determine initial course and speed, and at least two plots are needed to show a change in course or speed. As mentioned previously, if the DRT is manned, the operator computes the target's course and speed. He sends the course and speed information over the phones. Course and speed are displayed as shown in figure 14-7.

One important item of information that a commanding officer of any ship is particularly interested in is how close a contact will come to his ship. This is called closest point of approach (CPA).

As a surface plotter, you are required to determine the CPA and time of CPA. Chapter 16 will teach you how to use the relative plot in determining CPA and time of CPA. When you arrive at a solution, the information is sent over the phones so it can be recorded next to the track, on the DRT, surface summary plots, and surface recording board, just as the course and speed of the contact are recorded. Thus, the picture is completed for the evaluator, commanding officer, and flag officers in flag plot.

When the DRT operator has a correction of a contact's course and speed, he sends the corrected version over the phones. As the surface plotter, you will then cross out the old information and record the new data next to the time of correction.

Surface Plot as a Maneuvering Board

If the DRT is being used for some other purpose, such as navigation, A/S warfare, or shore bombardment, the surface plotter will have to supply the course and speed of contacts, as well as CPA and time of CPA. In addition to keeping a track of surface contacts, figuring their courses, speeds, and CPA's, the surface plotter must know how to determine the course and speed for own ship to take to intercept a contact or execute a change of station in a formation, and the time to get there. He also solves for direction and force of true wind.

You can see the surface plot requires a man who is well-rounded in surface tactical instructions and practices, proficient in rapid and accurate solutions of simple relative movement problems, and skilled in the use of standard plotting techniques and symbols. He also must work in close coordination with the DRT operator, and be capable of maintaining a comprehensive picture of the surface tactical situation under all conditions.

Surface Plot to Prevent Collision

During routine conditions, CIC watches may become monotonous—an ideal setup for catastrophe at sea. Since World War II there have been several instances where naval vessels were involved in collisions which could have been avoided if the watch in CIC had maintained an accurate surface plot, and had passed timely warning to the bridge.

To prevent collisions, one of the first solutions which should be derived from the surface plot is the closest point of approach. If an extension of a target's early plots passes through or near the center of the relative plot, the bridge must be informed of the danger of collision. The plotter must make certain that this warning was received correctly. Communication must be quick and positive. Lack of positive communication between the conning officer and the CIC watch officer has contributed to several collisions.

The hazards of the sea can be avoided only through constant vigilance. This was true long before development of CIC. But the age-old necessity for meeting this requirement now rests as fully upon the personnel in CIC as on those in any other shipboard watch station. But while giving due regard to possible danger from one quarter, the possibility of danger from another quarter must not be overlooked. For example, it could be fatal to concentrate all surface-search equipment on a target which appears to be on a collision course, thereby leaving most of the adjacent sea area unguarded. Do not let concentration on one matter of urgency blind you to the possibility of danger from another.

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Surface Plotting Hints

To date there is no substitute for the surface plot. The DRT will not at a glance give ranges, bearings, or the point of closest approach. Nor will the DRT serve as a collision preventer. A status board or other type of record, while useful for certain applications, helps to prove that the surface plot picture is worth a thousand words.

To ensure that your surface plot is complete, the following checkoff list should be consulted. There will be many situations where all of this information will not be necessary at any one time. Inclusion or deletion of the data listed below should be evident to CIC personnel from the type of operation in which the ship is engaged.

1. Use best practical scales.
2. Record scale of plot.
3. Use all plotting aids available.
4. Use standard plotting symbols and abbreviations.
5. Indicate source of information.
6. Show own formation.
7. Show other friendly ships and formations.
8. Show friendly ship station numbers and type letters.
9. Show friendly ship radiotelephone calls.
10. Indicate formation guide.
11. Indicate formation axis and center.
12. Number screen stations properly.
13. Indicate screen axis.
14. Show direction of base course and speed.
15. Keep own ship vector up to date.
16. Show AA coordination sectors.
17. Show limiting arcs of train for own batteries.
18. Know zigzag plan in use.
19. Plot and identify all contacts.
20. Show raid designation, composition, and course and speed.
21. Know radar and ECM guardships.
22. Know your surface search radar sector.
23. Plot clouds and weather.
24. Indicate wind direction and velocity.
25. Plot and identify nearby land.
26. Know how to plot reference points correctly.
27. Plot applicable lookout information.
28. Keep own ship in center of plot.
29. Plot neatly and legibly.
30. Show set and drift.

Surface Summary Plot

Like the surface plot, the surface summary plot is kept in terms of polar coordinates, usually on an edge-lighted, vertical plotting surface rather than a horizontal type plot.

Normally the surface summary is found only on large ships, such as cruisers and carriers. In CIC it usually is mounted in the vicinity of the DRT, surface plot, and surface status board. Another is in flag plot and also in commanding officer's tactical plot (COTP).

In practice, the surface summary plotter wears sound-powered telephones and is in communication with the surface-search radar operator, DRT plotter, and surface plotter. He normally stands back of the board and maintains an accurate plot of the positions of all other ships in the formation relative to his own ship, which is in the center. He also keeps an accurate relative track of all surface contacts within radar range. He plots bearings and ranges of contacts furnished by the surface-search radar operator or by the remote PPI-scope operator, and connects the successive plotted positions of each separate contact to show the relative track or relative movement line. In other words, by using standard symbols and abbreviations, he displays on the summary plot the same picture displayed by the PPI-scope. He also records the course and speed of all contacts determined by the DRT operator, as well as bearing, range, and time of CPA, as figured by the surface plotter.

Because space aboard ships is limited, it is not possible for all key personnel to have radar repeaters merely for evaluation purposes. Thus, the purpose of the surface summary plot is to display the tactical situation for flag officers in flag plot, the commanding officer in COTP, and the evaluator, CIC officer, and gunnery liaison officer in CIC.

SURFACE SUMMARY TO PREVENT FIRING ON OWN SHIPS

The location of all surface forces is displayed on the surface summary plot. Hence it provides a basis for determining safe firing limits, minimizing the danger of firing on friendly ships.

Target Designation

Target designation sectors prescribed for use in connection with antiaircraft gun control orders are usually limited by designated true

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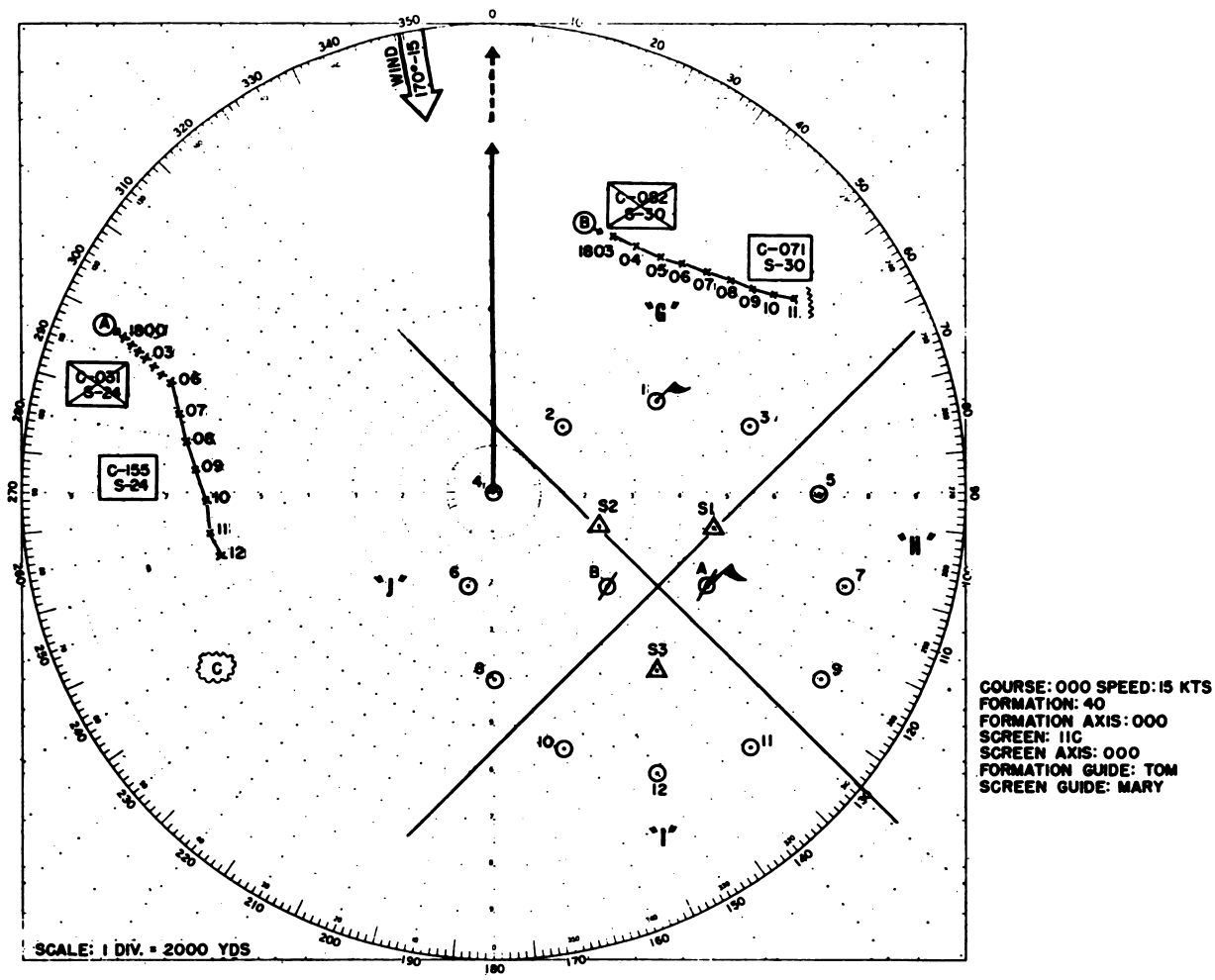

Figure 14-8.—The surface summary plot.

bearing (see fig. 14-8). NWP 31(A) contains instructions concerning these sectors. By plotting the sectors on the surface summary plot, the sector designation of all ships of the formation can be determined instantly.

Assistance to Lookouts

The surface summary plot can be useful in assisting the JL talker to coach lookouts in identifying contacts visually.

FORMATION DIAGRAM PLOT

The formation diagram and the surface plots are routine displays in CIC for all tactical exercises and operations. Every member of the CIC team must become familiar with their composition and use. This is necessary because these plots—along with the geographic plot, associated status boards, navigational charts, and surface-search radar—are the main tools of the CIC team in surface tactics.

As shown in figure 14-9, the formation diagram actually is a formation plot. It gives the assigned station of every ship in the formation relative to the formation axis or screen axis in bearing and the formation center or screen center in range.

The desirable manner for displaying the formation diagram is on a vertically mounted, edge-lighted, polar coordinate plotting surface. Due to limited space on many ships, however,

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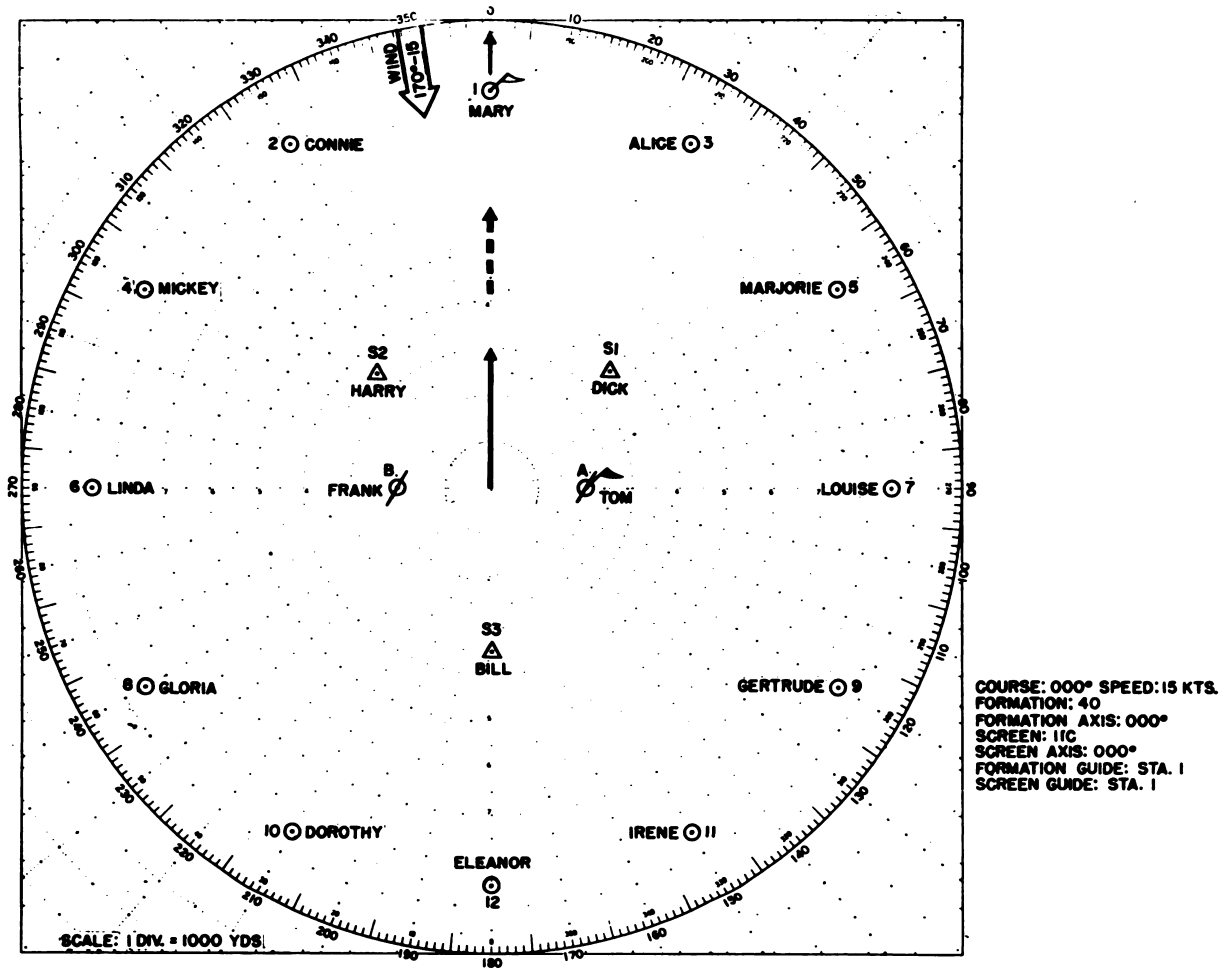

Figure 14-9.—Formation diagram.

this plot sometimes is kept on a maneuvering board.

Purpose of Formation Diagram

The radar PPI-scope presents a plan view of all ships in a formation relative to own ship in the center of the scope. By observing the scope, it is possible to determine the true bearing and range of every other ship in the formation and to detect any ship (including your own) which is off station. First, though, CIC must have a plot showing all ships in the formation in their proper station relative to own ship in the center. This relative plot is called the surface plot. Before the formation can be plotted on the surface plot, a formation diagram must be prepared.

Radarman 3 & 2, Volume 2 describes the purpose of a formation diagram and the procedures for selecting station assignments from tactical publications or operation orders and plotting them on the polar coordinate plotting surface. That you may better understand this chapter and other chapters concerned with plotting, we will now discuss a few terms used in plotting. For more specific terminology refer to *Radarman 3 & 2,* Volume 2.

Station Assignments

Each ship is assigned a specific station in the formation, and each station is fixed at a certain true bearing and range from the guide

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of the formation. As the guide (station A, fig. 14-9) steams through the water at a constant speed on a steady course, each station moves along with the guide, always at the same bearing and range. These station assignments for all ships in any formation are prescribed by the OTC.

Station Keeping

To keep on station, each ship determines the true bearing and range to the guide from own assigned station. Arriving on station at the predetermined bearing and range from the guide, each ship keeps station by steaming at the same speed on the same course as the guide, maintaining the same bearing and range. If the bearing and/or range should change, the individual ship changes course and/or speed to get back on station.

Station Changing

The station assignment of an individual ship may be changed at any time by OTC. If a change is made while the formation is underway, the individual ship has a problem in relative movement to solve on the maneuvering board, the surface plot, or the geographic plot. The formation will continue to steam through the water at formation course and speed while the individual ship must change course and speed to move from its old to its new station. When course and speed are changed, the station-changing ship takes a series of bearings and ranges on the guide until it arrives at the bearing and range of the new station. The individual ship then changes to formation course and speed and resumes routine station keeping.

Formation Axis and Formation Center

All stations in the main body of a circular formation are assigned relative to the formation axis in bearing and the formation center in range.

Screen Axis and Screen Center

All stations in the antisubmarine screen are assigned relative to the screen axis in bearing and the screen center in range.

Guides

Every formation of ships must have one ship designated as the guide or reference point for all maneuvers. Plotting its own correct station and the position of the guide (usually OTC), each ship determines from the formation diagram the true bearing and range of the guide. By maintaining the same course and speed as the guide (formation course and formation speed), with only minor adjustments, each ship is able to keep the guide at the previously determined constant bearing and range.

Rotation of Formation Axis

The term "rotation of the axis" means simply that the axis is changed a specified number of degrees to the right or left of the last previously designated axis. When the axis is rotated, the station assignment of each ship does not change relative to the axis; it does change relative to true north and relative to the guide. If the formation diagram is plotted on a vertical, edge-lighted, polar coordinate plot with a fixed outer bearing circle, the plot may be rotated the same number of degrees when the axis is rotated. In this way the formation plot is retained in proper relationship to the axis. Simultaneously the plotter is enabled to determine the true bearing of the guide and other ships by reference to the fixed outer bearing circle. However, if the formation plot is being kept on a maneuvering board or a fixed (nonrotatable) plotting surface, the entire formation must be replotted.

MANEUVERING BOARD

Such problems as solutions for course, speed, distance, time, etc., are accomplished on the surface plot or DRT. When more precise solutions are required, however, the maneuvering board is used. Chapter 16 explains the maneuvering board and how to use it.

SURFACE STATUS BOARD

The surface status board fulfills the same basic purposes regarding the surface situation that the air status board does in the air situation.

Surface status boards contain the following data items for use of surface plotters and other CIC personnel: cruising formation; formation axis, course, and speed; point of intended movement (PIM); PIM course and speed; bearing and range of the guide; and name and voice calls of all ships in company. The sectors and range responsibility of guardships may also be included.

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SURFACE CONTACT STATUS BOARD

ASW INFORMATION

OWN SHIP'S CUS. 000 SP. 15 BASE CUS. 000 SP. 15

NEAREST LAND CAPE HENRY BRG. 330° DIST. 50 TIME 1010

NEAREST AIRFIELD JETS OCEANA PROPS NAS NORVA

WIND FROM 290° / 10 KTS. TIME 1000 SEA STATE

SUN BRG. 089-60 ∠° TIME 1000 MOON BRG. ∠° TIME

WEATHER (CLEAR) V 20 A 0 T 0 B 0

315 045 STERN AWAY AWAY CHASE 240 120

SONAR MSG

CLASS

R/R

DOPPLER

BRG	RNG	BRG	RNG

SK	BRG	RNG	TIME	CUS	SP	CPA BRG	CPA RNG	CPA TIME	COMP	REMARKS

THIS SPACE CAN BE FOR FIRE MISSIONS, VOICE CALLS, OR OTHER IMPORTANT SHIP'S INFORMATION

ECM CONTACTS								EXPECTED			
RAK	FREQ	PRR	PW	ARR	BRG	TIME	EVAL	TYPE	FREQ	PRR	PW

Figure 14-10.—Example of surface status board.

The exact form of the surface status board varies from ship to ship. Figure 14-10 is an example of a typical surface status board.

COMMUNICATION STATUS BOARD

The communication status board differs from ship to ship, so no attempt will be made to describe one in detail. Regardless of the format used, however, the information to be displayed includes the following:

1. Channel number, frequency, and title of each CIC communication channel; also the number of each local control position.
2. Radio voice calls of all ships in the formation. In addition, the OTC, CTG, and TG calls of other formations.

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ELECTRONIC STATUS BOARD

The electronic status board may be made with the RADCM status board. Information to be placed includes:

1. Radar and radar detection guard assignments, listing the guardship and the type of guard or frequency band assigned.
2. Radar jamming guardships with the frequency band assigned.
3. Assignment of IFF codes.
4. Radar beacon guard and standby ships and code assignments.
5. Radio homing beacon guard and standby ships with identification letters, frequency, and effective code.

RADCM STATUS BOARD

The radar countermeasures (RADCM) status board should contain a record of the general characteristics of own radars—shipboard, submarine, airborne, and shore-based. Data recorded thereon should include:

1. Main or general purpose of the radar.
2. Operating frequency band in megacycles.
3. Various pulse repetition rates.
4. Various pulse widths.
5. Beam width.
6. Polarization (horizontal or vertical).
7. Various automatic rotation rates.
8. Whether lobe switching is employed.

STRATEGIC AND TACTICAL CHARTS

Strategic and tactical charts are used for recording additional information for evaluation. Maintenance of these displays is not the responsibility of the Radarman Third or Second, so the charts are not covered in this chapter. To be a good Radarman, however, you should find out where these charts are used on your ship and how you can contribute to giving information to be shown on them.

OTHER DISPLAYS AND STATUS BOARDS

There are other types of displays and status boards used in CIC. Some of these are the summary plot, tote board, conversion plot, and air status board. Because they are concerned with the air picture, they are explained in the chapter on air plotting.

QUIZ

1. To whom does the CI net talker make his first report on an air contact?
2. Define relative bearing.
3. If you saw a bearing written 150°, would it be a relative or true bearing?
4. What type of plot is kept on the DRT?
5. In timing plots, when are four digits used?
6. Where are surface summary plots normally kept on large ships?
7. By what means do all ships maintain stations in a formation?
8. When is a surface contact reported to the OOD?
9. How often are CI net reports made on surface contacts?
10. On what status board would you find the assignment of IFF codes?

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CHAPTER 15
AIR PLOTTING

OBJECTIVE OF AIR PLOTTING

The process of handling information in CIC involves four major steps: collection, display, evaluation, and dissemination. Air plotting is primarily a function of display. Display is accomplished by means of plots, status boards, logs, data boards, and is necessary in order that information may be properly evaluated. Radarmen are responsible for maintaining displays of the collected information for inspection by those officers in CIC (the evaluator, RCO, CIC officer, air controllers, and gunnery liaison officer) who must take action based on the accumulated data. Therefore, the objective of air plotting is to present a neat, accurate, up-to-the-minute picture of the position and track of all aircraft in the area under surveillance.

In this chapter we will discuss the displays and status boards which are of primary importance during air defense operations and some of the information which may be found on them. No attempt is made to prescribe the exact format of these displays; the particular mission of the ship, and available space and the arrangement of equipment will greatly influence layouts. The displays and status boards discussed are:

1. Summary plot and tote board.
2. Conversion plot.
3. AA coordination plot.
4. Status boards.

This chapter also contains the procedure for tracking air contacts and the use of standard air plotting symbols and abbreviations. Along with the foregoing will be discussed the methods of computing courses and speeds, designating raids, plot raid estimates, altitudes, fades and splits.

SUMMARY PLOT

Air plotting is done, primarily, on the summary plot, sometimes called the vertical plot, which is, in almost all cases a vertical edge-lighted transparent plastic board like the one illustrated in figure 15-1. It is scribed in such a manner so as to depict a polar coordinate presentation. Bearing lines radiate from the center of the board and circles are scribed to give graduating ranges. These circles may equal 1, 5, 10, 20 or 50 nautical miles per circle depending on the amount of coverage desired. Normally the 20-mile-per-circle-scale is used so the coverage is out to 200 miles.

As an air plotter you will wear sound-powered telephones connected to the same circuit as those of the radar operators who read range and bearing of contacts from the scope. In addition the radar operator must give you all the information possible on the altitude of planes, both bogey and friendly, the size of the contact, the IFF code showing, possible splits, jamming, and any other information that he can get from his radar. As an air plotter, you must not only expect, but when not supplied, request all this information. Besides plotting information given to you by the radar operator, you must figure course and speed of contacts, estimate probable position of bogies when you fail to receive radar reports when contact fades, and plot raid number symbols.

Notice in figure 15-1 that air plotters stand and work from the back of the board. So, in order to make a plot that can be easily read and understood, you must learn to write and plot backwards so the information can be read from the front of the board.

Different colored grease pencils are used in writing on the summary plot's plastic surface. Most ships use a color scheme such as:

Red or orange for bogies and bandits.

Yellow for friendly CAP.

White to show the position of picket ships, patrol aircraft, and other ships' positions in the formation or disposition.

The Georef System

Frequently, a grid of one kind or another will be employed on a summary plot. It will be

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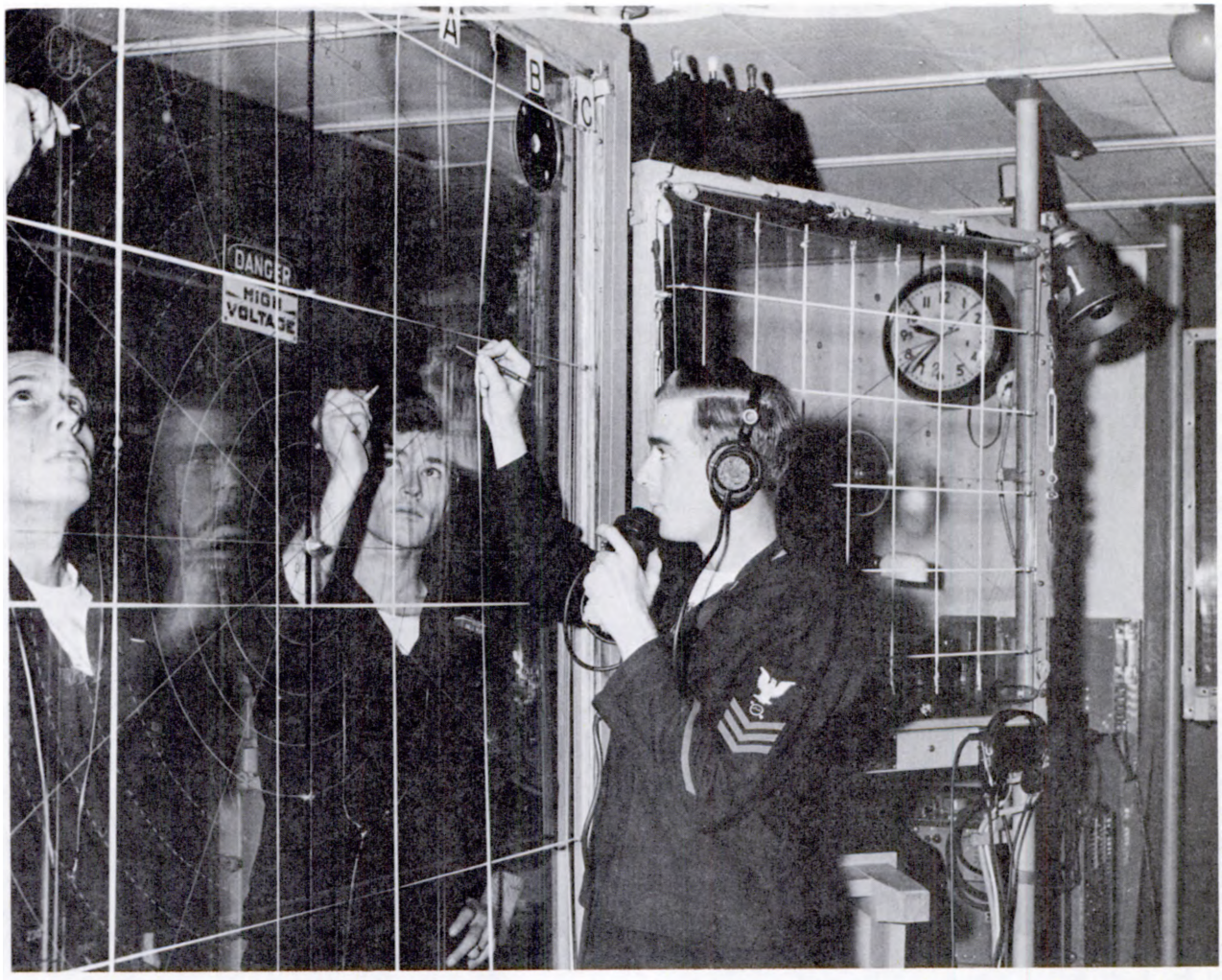

Figure 15-1.—Summary plot using GEOREF system.

necessary to rearrange the normal polar coordinate board to conform with the grid in use. Figure 15-1 illustrates the elastic string system of plotting using the Georef system. This is the most common system in use. Elastic strings are strung between two metal strips and mounted on opposite sides of the summary plot. With two sets of these strings mounted north-south and east-west, squares are formed across the face of the plot. By closely spacing drilled holes for attaching the strings along the whole length of each metal strip, strings can be placed at almost any distance apart, thus allowing for the difference in Georef scale as latitude changes. Slots approximately 10 inches in length are cut near the end of each strip and a wing nut inserted to fasten them to the plot frame. By loosening the wing nuts, the strips can be moved back and forth a full 10 inches of movement. Thus the movement of the ship through the water can be compensated for by periodically moving the strings (grid lines) to keep the position of the ship accurate in relationship to the Georef grid. Grids can be lettered either on the face of the board between strings with a grease pencil or by attaching small paper or cardboard tabs on the strings.

To Use This System

The Georef grid lines or strings are placed over the summary plot board and labeled according to own ship's position as accurately determined by navigation.

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Own ship's contacts are plotted on the back of the summary plot in range and bearing from the ship which is always located in the center of the board. The raid coordinates can then be read directly in Georef. The method of reading the Georef is to the right and up or down. In other words, if a contact is plotted in a position of JK 1020, first go to the right of the board to J, then up or down to K, which locates the bottom left corner of the square. Now go over to the right 10 units and up 20 units of that square.

Incoming Georef raids reported from other ships are handled in the opposite manner. They are plotted on the board in Georef and translated for gunnery and ship control into range and bearing.

The plotting symbols and abbreviations are identical to the ones used in polar coordinate plotting.

One thing to remember when using the Georef system is that reports plotted from other ships and information plotted from own radar will not be accurate in grids unless your ship's position is accurately placed in the proper grid. The strips to which the strings are fastened are moved in the opposite direction to the ship's movement periodically to compensate for the movement of the ship. This is done whenever the ship is 5 miles from its plotted position. With a 20-knot point of intended movement (PIM), 3 hours of operation can be handled before relettering of grids is necessary.

Geographically fixed information such as land, hazards to navigation, etc., must be replotted when the strings are moved.

You will learn more about the Georef system when you study *Radarman 3 & 2,* Vol. 2. It is explained in detail in chapter 5 of that book.

USE OF SUMMARY PLOT

The summary plot is used to display friendly and enemy aircraft and is: essential to the function of evaluation, an aid in controlling aircraft, a tactical picture of the air situation for command, and an essential source of information for gunnery liaison personnel.

The tracks of friendly combat air patrol, attack, search, observation, rescue, and other aircraft are plotted to assist in the over-all evaluation and action required. The display may also be employed to assist in homing lost planes or fix the position of downed aircraft or crews.

Although the summary plot is primarily a picture of the air situation, surface forces which relate to the air picture are shown. Also reference points, dangers to air navigation, wind direction and velocity, position of sun, positions of outlying picket forces and raid designations are presented on this board.

SOURCES OF INFORMATION

To obtain the information that is displayed, several sources are used. The primary source is the ship's radar, augmented by the radar of other ships in the force, picket ships, and AEW aircraft. In order to make it possible for all CICs to have the same information, a mutual exchange of this information is carried out by means of radio (voice and CW). Figure 15-1 illustrates a man plotting Georef reports and information received on the combat information net from other ships in company. In turn, he also reports any information that is plotted on the back of the board by the summary plotters as received from radar. Use of the strings and by positioning own ship in the correct grid enables the CI net operator to convert a range and bearing from own ship to Georef reports rapidly.

Visual information in the form of lookout reports, CAP or search plane sightings are received in CIC to be displayed. ECM intercept reports are plotted, along with intelligence data and coast watcher reports. Any information, regardless of the source, when promptly and accurately displayed, is valuable to the evaluator.

PLOTTING SYMBOLS AND ABBREVIATIONS

Standard plotting symbols and abbreviations which are of special importance to Radarmen are the result of many years of development through actual use in the fleet.

Standard plotting symbols and abbreviations for air tactical plotting and tracking are shown in figure 15-2. They are used principally in connection with rapid plotting and tracking in CIC, flag plot, and commanding officer's tactical plot.

Remember these symbols must be made large enough to be seen easily by anyone standing some 4 or 5 feet from the plot.

Bogey is a code word used to indicate an unidentified aircraft. When it is identified as friendly, through IFF, by visual identification, or through some other source, you plot it as a

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(a) AIR

SYMBOLS

•	Dead reckoned position of controlled aircraft
X or)	Unidentified or enemy aircraft (Bogey or Bandit)
SB AH S-480	Amplifying data. Meaning: 1 Bogey, Angels high, speed 480. Note: Course is eliminated since it is apparent from observation of plot. (Course may be used for surface plotting.)
⊙	Friendly (Friendly aircraft)
⊗	Merged plot (Friendlies and Bogeys at same location.)
∅	IFF only
#3	Mode number of IFF (placed beside track at point of mode identification)
Ⓔ	Emergency IFF (approximately twice the size of friendly symbol)
Ⓔ	Emergency IFF only
N	Challenged. No IFF reply.
~~	Fade line
═══	Jam fade line
Ⓙ	Jamming (Show direction by arrow)
⊞	Window (Show movement direction by arrow)
50°	Sun or moon (figure represents angle of elevation)
⋰⋰	EPA (Estimated Position Arc)
①	Raid designation

Note: Amplifying data on air plots should be displayed on the tote board when space is provided.

For antisubmarine symbols, see NWP 24

ABBREVIATIONS

AEW	Airborne Early Warning
SB	Single Bogey
FB	Few Bogeys (2-10)
MB	Many Bogeys (over 10)
A	Angels or altitude (thousands of feet)
AVL	Altitude very low (below 2,000 feet)
AL	Altitude low (2,000 to 10,000 feet) (Note: Should be used where measurement has actually been taken.)
AM	Altitude medium (11,000 to 25,000 feet)
AH	Altitude high (26,000 to 40,000 feet)
AVH	Altitude very high (above 40,000 feet)
C	Course
S	Speed
P	Planes
TH	Tallyho
F	Fish (torpedo planes)
R	Rats (fighter planes)
B	Bombers (high level)
H	Hawks (dive bombers)
LO	Lookout report
COM	Radio report
SON	Sonar report
PIN	Enemy radar signal
VOL	Enemy guided missile signal
RAK	Intercepted electronic transmission

Figure 15-2.—Symbols used in air plotting.

friendly contact—a circle. A bogey is identified by a cross. If a bogey becomes a BANDIT, which is the code word for an identified enemy contact, you continue using the cross symbol. All bogies are treated as bandits until identified.

By combining the two symbols, friendly and bogey, you have the merged plot. Merged plots are reported by the radar operator when he has a friendly and a bogey or bandit at the same range and bearing. This happens most frequently when friendly planes intercept an enemy raid and there's an air battle in progress.

At times, due to the limitations of radar, you will be unable to pick up a contact because the aircraft may be flying through a null area, or low enough to escape detection by your air-search radar. It is common under these circumstances to pick up IFF only, which is marked as the friendly symbol with a line drawn through it. The radar operator will generally report range and bearing to IFF only, and it may not match up with the position you expect. Here you

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will have to evaluate your plot and match up IFF reports with radar reports whenever possible.

PLOTTING TECHNIQUE

There must be no hesitation in plotting the proper symbol at the correct range and bearing. In fact, this process should be completely automatic. Thus, it is essential that you be completely familiar with the symbols and abbreviations used in air plotting to insure rapid and accurate plotting.

Immediately upon receiving a report of a contact from the radar operator you should automatically do the following:

1. Place your pencil onto the plot at the correct range and bearing, then quickly plot the proper symbol.
2. Place the time the report was received alongside the plot.
3. Connect each successive plot with straight lines. (For neatness and readability it is best that space be left between the plots and the ends of the line.)

Time Rule

Time is spoken digit-by-digit. Time is recorded in two-digit figures which represent the minutes past the hour. The only exceptions to this are the first in a series of connected plots, and the first plot in a new hour, which are recorded using four digits. For example, take a look at a typical raid illustrated in figure 15-3. The first plot shown is time 1000^2 and 1 minute later the next plot is 01^2. Between 15 seconds prior to and 15 seconds after a minute, time is referred to as being ON THE MINUTE. Between 15 seconds after and 15 seconds before the next minute, the time is considered to be PRIME. Prime times are plotted with the exponent "2".

Raid Designation

Each air raid is designated by a code word (BOGEY, BANDIT, or FRIENDLY), followed by a number in consecutive order of appearance. The raid designation number only, is used on the plot and is placed in a circle at the head of the track with an arrow pointing in the general direction in which the raid is moving. The numbering of raids facilitates the identification and tracking of raids by all ships, and the applicable code word and number are always used in reporting the raid. Figure 15-3 shows the track of a bogey designated raid 3.

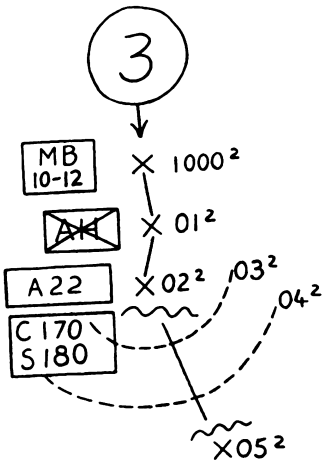

Figure 15-3.—Typical raid track.

To help keep the numbering system in order, two circles are drawn at the top right and left of the summary plot. These are labeled NEXT BOGEY and NEXT FRIENDLY in that order. The maintenance of these is the responsibility of the summary plotters.

As an aid to the plotters in keeping a neat plot, especially in drawing the raid designation circles, many ships have found it useful to make a template out of wood or plastic with a circle (the proper size) cut in one side of it. The other side has a square cut for information boxes. To obtain a neat circle or square, the plotter has only to place the template against the plotting board and mark through the proper hole with his grease pencil.

Information Boxes

Most information that concerns itself with the raid (altitude, composition, course and speed, "TALLYHO" reports, "SPLASH" reports, etc.) is placed in information boxes alongside the track. If a tote board is used, this information will be displayed there. Plotting suggestions for information boxes are:

1. Keep boxed information neat and legible. The top and bottom sides of the box are parallel to the bottom of the board, and the other sides are drawn perpendicular to these.
2. Put information boxes on opposite sides of the track from the time.
3. Keep the boxes behind (with reference to location) the last reported plot in order to avoid the possibility of the track running through the box.

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4. Keep the boxes up-to-date. When new information is reported that changes, or contradicts older information, add it in a new box in the proper place; then put a a corner-to-corner cross inside the old box, indicating that it is old information.

Composition And Altitude Estimates

Within the first few minutes the radar operator will give his estimates of composition and altitude. This is not an accurate calculation but merely an estimate made from the size and initial range of the pips on the radar scope. Later, he will make a better estimate.

Two composition estimates are usually made:

1. The first estimate is a general one such as one bogey, few bogies, many bogies, etc. If possible, this estimate is given with the first report.
2. The second estimate comes after the operator has had a chance to check the pip more closely. It should be a numerical estimate.

In the illustration (fig. 15-3), because the specific number of planes was given only a minute after the initial plot, it is legitimate to place this figure—10-12—in the same box with the abbreviation MB. If this estimate comes later, or if a different estimate is made, it is placed in a separate box beside the plot when this estimate is made and the letter P (for plane) is placed in the box behind the number. In this illustration it would be 10-12P, boxed.

Two altitude reports are usually made:

1. The first report contains a general estimate of the altitude of the target expressed as altitude high, altitude low, altitude very low, altitude medium, altitude very high. (See abbreviations listed before.)

The two terms generally used by the radar operator are: ALTITUDE HIGH and ALTITUDE LOW and are plotted AH and AL.

2. The second report will consist of the best obtainable altitude in feet determined by own radar, other ship's radar, aircraft report, or such other information as may be available.

Notice in figure 15-3 the altitude was first estimated as high then later at time 02^{2} reported at altitude 22,000. The letter A is the abbreviation for ANGELS or altitude in thousands of feet.

Course and Speed

Course and speed should be determined and plotted after the first 3 minutes of track and continually checked and rechecked thereafter to make sure that any significant changes are noted. A minimum of 4 plots (3 minutes of track) are required for the initial solution of course and speed; a minimum of 3 plots (2 minutes of track) are required for determining a change in course and speed beyond a range of 20 miles; and 2 plots (1 minute of track) may be used for determining a change in course and speed within a range of 20 miles.

1. Computing course: Course is the mean line between a number of plots, usually 4 (3 minutes). It is computed normally to even tens of degrees. Figure 15-4 illustrates how the course is determined.
2. Computing speed: Speed must be determined as soon as possible and as accurately as possible. Depending upon range, as explained before, speeds can be obtained from 1 minute of plot but, of course, this is not as accurate as a speed obtained over longer periods. The longer you wait the more accurate the speed. However, the most satisfactory compromise is with 3 minutes of track, where the 3-minute-speed rule can be applied—"distance covered in yards by the contact in 3 minutes, less two zeros, equals the speed of the contact in knots." A more suitable computation for determining the speed of an air contact is mentioned below. Three minutes equals 1/20th of an hour. In 3 minutes the contact will travel 1/20th the distance he will travel in 1 hour, and (distance traveled in 1 hour is the speed, 260 MPH or 260 Kts, for example). Measure the actual distance in miles traveled by the contact in 3 minutes, double that figure and add a zero which means that actually you are multiplying by 20. Work this out for several other periods: for 1 minute, 2 minutes, 4 minutes, 6 minutes, according to instructions on figure 15-4.

Fades

The aim of fade plotting is to present all the possible positions at which the bogey might appear. Since we are primarily interested in the bogey's advance toward the formation, the fade plot is drawn with this in mind.

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A normal radar fade is plotted with a wavy line about 1/2-inch long, placed between the last plot (fix) and the base, parallel to a tangent to a range circle. This wavy line (fade symbol) is illustrated in figure 15-3. A similar wavy line is placed outboard the plot where the raid reappears. The two plots are joined by a solid line in the usual manner. A jam fade is plotted in the same manner using, instead of a wavy line, two parallel lines about 1/2-inch long.

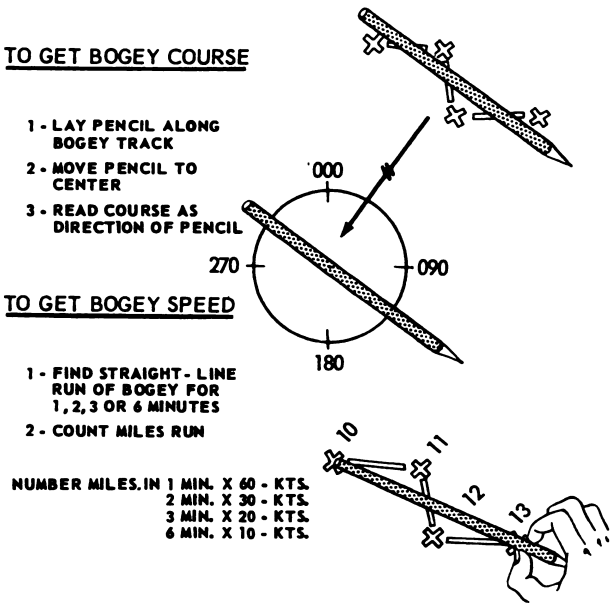
TO GET BOGEY COURSE
1 - LAY PENCIL ALONG BOGEY TRACK
2 - MOVE PENCIL TO CENTER
3 - READ COURSE AS DIRECTION OF PENCIL
000
090
180
270
TO GET BOGEY SPEED
1 - FIND STRAIGHT - LINE RUN OF BOGEY FOR 1, 2, 3 OR 6 MINUTES
2 - COUNT MILES RUN
NUMBER MILES IN 1 MIN. X 60 - KTS.
2 MIN. X 30 - KTS.
3 MIN. X 20 - KTS.
6 MIN. X 10 - KTS.
10
11
12
13

Figure 15-4.—Air contact course and speed.

Estimated Position Arcs

Estimated position arcs consist of dashed semicircles separated by distances depending upon the last known speed of the BOGEY. EPA's represent points of possible positions of the raid at specific times. The last known fix is used as the center or origin from which each arc is drawn. An EPA will be plotted on the minute from the time of the last known fix until another fix is obtained, with the time being placed at one end of the arc. Notice in figure 15-3 the EPA is positioned toward the base so that the two ends fall at the same range as the last known plot.

Estimated position arcs are used to indicate dead reckoning positions when a raid fades. If the raid is in a fade, a fade symbol is used and then the EPA's are drawn. When the radar operator fails to report on a raid, and no fade has been announced, EPA is used without the fade symbol. Radar operators sometimes become preoccupied with other raids or contacts and do not have time to report a raid every minute. This does not lessen the plotter's task of keeping an up-to-date plot on the bogey. Because of extremely crowded plots, fades over extended periods, and similar problems, it may be found desirable to limit the length of the arcs, decrease the frequency of plotting the arcs, or dispense with their use entirely. The CIC officer or person at radar control must use discretion in the use of EPA's realizing the purpose for which they are designed and keeping in mind the particular situation at hand.

Air Raid Splits

If a raid splits, the designations of the separate parts of the raid are to be given a letter suffix in addition to the primary designator. These suffixes are assigned consecutively, clockwise, by the ship that reports the raid split. The CI (control) ship may accept these raid designations, or it may assign a new raid designation number to one or more of the split parts. If two or more parts of the target fall on the same bearing line, the one nearest the force, group, or unit will be given the first letter of the alphabet. If a split raid with secondary designators (letter suffixes) assigned should split again, the same procedure for applying a third designator (numeral suffix) is applied.

PLOTTING THE FRIENDLIES

Friendly contacts are plotted, timed and connected in the same manner as bogey contacts, but there are differences in the information necessary on the two tracks. Notice the plot of friendlies in figure 15-5.

On the friendly track, no fade lines, or estimated position arcs are used. If a contact is picked up by the radar operator and later begins to show IFF it will be designated as friendly 1, 2, 3, etc., and plotted F-1, F-2, F-3, and so on. When the contact is positively identified as CAP, or some other type friendly plane, the call sign is placed next to the track. (The marking RED 1 & 4 as shown in the illustration.)

One important addition to the friendly track is the mode of IFF shown by a friendly contact. If the mode showing is mode three, this information is plotted—#3—and is not boxed. The numeral symbol (#) and the number itself should be large enough to be easily read.

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Whenever possible the name of the division, or divisions, if known, is placed in abbreviated form beside the track and boxed. If there is a possibility that abbreviations might be confusing or misinterpreted, print the entire name or names of the divisions.

Altitude is recorded by plotting in a box the A and the altitude in thousands of feet.

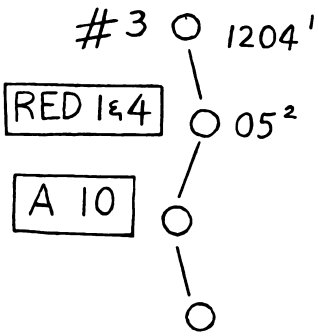

Figure 15-5.—Information plotted along friendly track.

ADDITIONAL SYMBOLS AND ABBREVIATIONS

One of the most important symbols in air plotting is the symbol for emergency IFF. If a friendly plane is in trouble, the pilot will turn on his emergency IFF signal which will be reported to you by the radar operator.

This symbol is a circle, the same as the friendly symbol, only the letter "E" is plotted inside the circle. The emergency IFF symbol should be at least twice as large as the friendly symbol. You develop the track of a friendly showing emergency IFF exactly as you would the regular friendly.

The symbol for Emergency IFF only is that for Emergency IFF — a circle with an E — with the addition of a diagonal line.

When the radar operator reports JAMMING the symbol plotted is a circle with the letter J on the outer rim of the plotting table on the approximate bearing reported by the operator.

The sun or moon symbol looks exactly like a kindergarten drawing of a sun or moon. This is an arc with rays going out from the arc and is plotted on the edge of the board at the proper bearing. The angle of elevation of the moon or sun should be included in this symbol. The position of the sun is very important information to an aircraft controller. The best intercept tactic is to bring the fighter planes out of the sun; therefore, plot in the symbol for the sun whenever possible; the lookout can supply this information when required. This information should be obtained regularly as the sun changes position quite rapidly. There are five rather important abbreviations to be used when friendly planes intercept an enemy raid; they are: TH, F, R, B, and H. TH is the abbreviation for TALLYHO which is the code word used by friendly pilots when they sight the enemy. F means FISH, or enemy torpedo planes; R for RATS, enemy fighters; B is BOXCARS or BOMBERS; and H is HAWKS or enemy dive bombers. Your plotting job is to plot the TH for tallyho and then, in the same box, record all information given by the pilot. You will not be on the same circuit as the pilot, therefore this information will be relayed to you by the air controller or someone on the same circuit, or you might receive this information from some ship in company that is controlling aircraft. If the pilot reports: TALLYHO, 10 RATS, 5 HAWKS, the box would have TH-10 R, 5 H. The tallyho information box should be as close to the merged plot as possible. (Target and friendly appear to merge as one pip.)

You should now be ready to practice these procedures in drills. Have someone read ranges and bearings of a "canned" (simulated) problem to you. As you become more proficient, the time lapse between each contact should be decreased. When you can plot at the rate of five to six contacts a minute, you're doing well. At the same time memorize the standard air plotting symbols and abbreviations; learn the standard plotting and tracking procedure; and accomplish all plotting rapidly, accurately and neatly. The information displayed by the summary plotter is vital in any combat operation, and the effectiveness of evaluation is dependent upon the accuracy of the data displayed on the plots. Later in this chapter we will discuss the problem of dead reckoning aircraft, but first let us see how the tote board is used in conjunction with the summary plot.

THE TOTE BOARD

The arrival of high-performance aircraft has made it necessary to greatly extend the surveillance area about a force. This means considerably more information must be displayed than before. If everything were put on the summary plot the resultant congestion of information would diminish the value of the plot to a marked degree. For example, if there were two plotters working

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on the back of the plotting board, and each were plotting six contacts, they would be working near the limits of human ability. This is particularly true if they were required to place all information alongside the track and compute courses and speeds of all contacts. Consider also that a summary plot with all this information displayed would be so cluttered that it would be of no practical use to the evaluator or anyone else.

The solution to these problems is to place part of the information on another plot called a TOTE BOARD.

INFORMATION DISPLAYED ON TOTE BOARD

The following information is normally displayed in the three major sections of a tote board: (1) CAP, (2) bogey, and (3) other friendlies. (Follow this discussion in figure 15-6.)

The CAP section of the board includes: the event number as given in the Op-order, time off, composition (how many and type of CAP) mission (job A/C are to perform) voice calls, control ship, and radio channel; station (range and bearing of CAP), altitude, and IFF mode; state report (how much fuel, oxygen and ammunition available) with time of the report.

The BOGEY section is divided into two subsections, BOGEY TRACKS and INTERCEPT TRACKS.

Bogey information is carried under BOGEY TRACKS. It includes: bogey designation (track); reporting ship; composition; altitude; course and speed; and remarks, for example, splash, heads up, away, etc.

Information about CAP taking raid is carried under INTERCEPT TRACKS. Included are: CAP track call or voice call; observed composition and altitude on break-through. "(Tally Ho)."

In the OTHER FRIENDLIES section the following is recorded: track number of friendlies other than CAP (these may be self-evident abbreviations of the aircraft radio calls) and remarks. Notice under the TRACK/CALL the voice call of ANYFACE 1 is abbreviated AF-1 and controlled by YORKTOWN (YK). The remarks section indicates that AF-1 is an AEW plane.

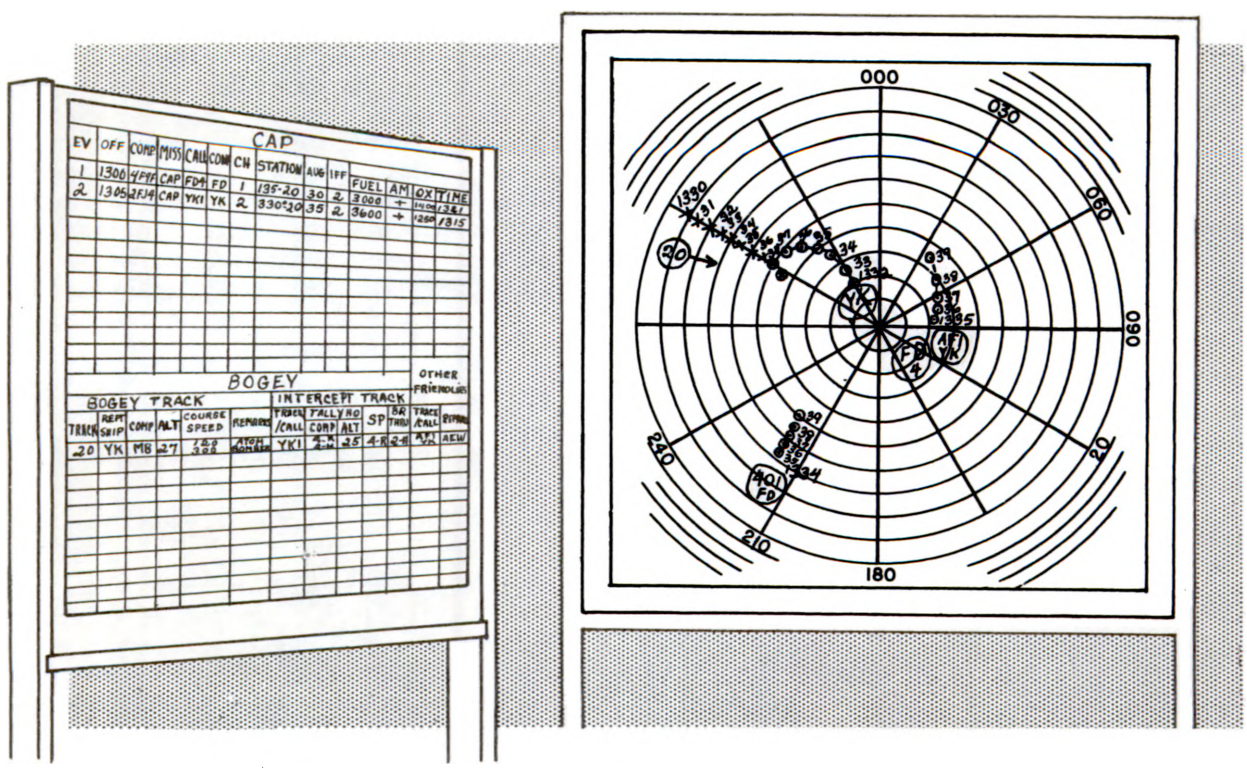

Figure 15-6.—Tote board (left) and summary plot (right).

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HOW TO KEEP THE TOTE BOARD

The ideal method of maintaining a tote board is to use two men. One man is behind the board wearing a radiotelephone headset connected to the AC (air control) net. He records information in the CAP section as received on the radio, or from any member of CIC. On certain occasions the AC net is combined with the CI (combat information) net.

The other man, in front of the board, wears sound-powered telephones connected to the air search radar operator and the RCO. This man's duties are somewhat more complicated than the AC net plotter, because he has to work on two boards; the tote board and the summary plot. This is what he does:

1. Watches the summary plot and lists new bogies on tote board under the bogey section.
2. Uses his grease pencil to measure distance raid traveled in a certain time by plots on the summary plot, computes speed, and determines course.
3. Receives bogey composition from own radar operator and records under the BOGEY section.
4. Records altitude of raid as received. (Depending on circumstances this may be from own radars or from the CAP. If from the CAP, the plotter will get the data from RCO, via the air controller. The air controller is in touch with the CAP.)
5. Records any information relayed to him by the CI net plotter, picket net plotter and air controller.

Figure 15-6 shows the summary plot (sometimes called vertical plot) and tote board in a simple air defense situation. The CAP section shows that FAIRDALE 4, controlled by FAIRDALE on Channel 1, is stationed at 135° 20 miles at 30,000 feet. FAIRDALE 4 will show IFF Mode 2. At 1321, FAIRDALE 4 had 3000 pounds of fuel, ammo plus, and 1400 pounds oxygen pressure. The same types of information are also shown for *Yorktown 1,* who is under *Yorktown's* control. In the bogey section, bogey 20, which is at 300°, 60 miles on the summary plot, is being reported by *Yorktown;* it is many bogeys at 27,000 feet, course 120°, speed 300 knots, and is a suspected atom bomber; it is being intercepted by *Yorktown* 1, controlled by *Yorktown* which is Friendly YK 1 on the plot. Also on the plot is Friendly AF 1 YK which is shown as the tote board ANY FACE 1 *Yorktown,* an AEW patrol. Friendly 14, closing from 220°, 401 FAIRDALE, is a returning strike.

DEAD RECKONING

When CIC is controlling aircraft, it's necessary to know where the planes being controlled are at all times. In order for the controllers to keep positive control, and for the plotters to keep an accurate track of aircraft, they must be able to dead reckon. The need for dead reckoning becomes apparent when we realize that radar information is subject to fades, mechanical failures, and enemy jamming. At this point you already know how to track enemy contacts in fades by the use of fade lines and estimated position arcs. Now let us see how to maintain the tracks of friendly planes on the summary plot.

DEVELOPING THE DEAD RECKONING TRACK

As DR plotter you'll wear headphones connected to the voice radio circuit used by the air controller. You'll hear the orders he gives the planes and the answers from the pilots. By using this information, it's possible to show on the plotting board exactly what the fighter planes are doing at any time.

Dead reckoning is considerably more difficult than raid plotting since there are no constant radar reports to help you. You're on your own. Consequently, you must have DR procedure at your fingertips. An error of 3 miles in the DR track may mean the difference between intercepting an enemy raid or allowing it to break through.

Start of Track

The DR track must begin at a fix, either visual, radar, or from the center of an established orbit.

The Track

A DR position for friendly aircraft is plotted every minute, using a solid dot. (See fig. 15-2.) Between these dots are a series of dashes, each dash representing a 15-second time interval. Alongside the dots is placed the time, to the nearest minute and exponent, in the same way as in other types of air plotting.

Occasionally the radar operator may be able to get a radar fix on the fighters. This serves as a check on the DR plot. When a radar fix is obtained, continue to dead reckon from the point to the fix, since it is more accurate than the DR position. DR uses new courses and speeds from the time a pilot acknowledges for the orders.

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The controller orders the pilot to fly the plane in a desired direction by giving him a "VECTOR" followed by 3 numbers which is the MAGNETIC HEADING necessary for the plane to fly, in order to make good a true direction over the ground. However, if the air controller knows the plane's heading, he may dispense with the word VECTOR and order the plane to alter course by saying, "Port 20°" or "Starboard 20°", etc.

A magnetic compass needle does not always point to true north but varies according to the position of the compass on the earth. This is called variation and must be considered both by the controller in ordering headings to the aircraft and by the plotter who is required to dead reckon during plotting. The ordered magnetic heading must be converted to a true heading in order to plot the plane's track over the ground. (For plotting purposes it is accurate enough to use the nearest multiple of 5°.) The plotter must add easterly variation to and subtract westerly variation from magnetic heading (VECTOR) in order to get a true heading. Normally the watch petty officer determines variation from the chart of the area in which your ship is operating and displays this variation on all status boards. Variation is discussed further in chapter 17.

Speed Converting

Along with the VECTOR the controller tells the pilot what speed to fly. The plotter must be able to convert a speed into miles-per-minute in order to enable him to DR. When the speed terms "SAUNTER," "LINER," "BUSTER," and "GATE" are used the controller should inform the plotter how many miles-per-minute are made for the type of aircraft being controlled. To facilitate DR plotting, it is good practice to mark off in advance, on suitable straight edges, speed scales for various types of aircraft which will be or might be controlled. This enables the plotter who is DR-ing to plot quickly and accurately the distance traveled each minute.

The term SAunter means fly at power and speed giving best endurance.

The term LIner means fly at power and speed giving maximum cruising range.

The term BUster means fly at maximum continuous speed (power).

GAte means fly at maximum possible speed (power).

Turns

The radius of a turn is dependent upon three factors—the rate of turn being used, the speed of the aircraft, and its altitude. The rate of turn governs the time it takes to complete any portion of an orbit. In order to discuss turns, we must make the distinction between turns for propeller-driven aircraft and turns for jet aircraft.

1. A standard turn for propeller-driven aircraft is 3°-per-second which means that the aircraft will turn 3° for each second in the turn. A hard turn for propeller-driven aircraft is 6°-per-second.
2. A standard turn for jet aircraft is normally considered 1-1/2°-per-second which means that the aircraft will turn 1-1/2° for each second in the turn. A hard turn for jet aircraft is normally considered 3°-per-second. (Jets can turn without difficulty at the rate of 3°-per-second when below an indicated air speed of about 225 knots.) When above this IAS or when on instruments, they normally turn at the rate of 1-1/2°-per-second.

As altitude and speed increase, the radius of the turns will increase, but the time to complete the turns will remain the same. Since the three factors are interdependent in governing the radius of a turn, changing any one of them will change the radius of the turn. For example:

1. Increasing the rate of turn will decrease the radius.
2. Increasing the speed will increase the radius.
3. Increasing the altitude will increase the radius.
4. Increasing proportionately the altitude and rate of turn will keep the radius the same.
5. Increasing proportionately the speed and the rate of turn will keep the radius the same.

Information on sample turns for plotting purposes is given in tables 15-1 and 15-2.

A 90° turn takes one-half the time required for a 180° turn; a 45° turn takes one-quarter of that time. Turns of less than 45° are not timed, and no turning circle is used. Turns greater than 45° are figured to the nearest 45°. For example, a 60° turn is timed as a 45° turn, and a 70° turn is timed as a 90° turn. Figure 15-7 is a good example of a DR track through a turn. When the air controller gives the fighters a new order, such as a course, speed or altitude

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change, continue on the same DR track until 15 seconds after the pilot acknowledges the order before executing it on the plot. This delay is to allow for the time lag between the "WILCO" of the order and the actual execution of the order by the pilot.

Table 15-1.—Standard Turns. Radii and time to turn 180°.

Speed	Radius in miles		Time in minutes	
	Prop	Jets	Prop	Jets
150	1	1-1/2	1	2
210	1-1/4	2-1/4	1	2
240	1-1/2	2-1/2	1	2
300	1-3/4	3-1/4	1	2
400	2-1/4	4-1/2	1	2
500	2-1/2	5-1/4	1	2
600	3	6-1/4 to 6-1/2	1	2

Table 15-2.—Hard Turns. Radii and time to turn 180°.

Speed	Radius in miles		Time in minutes	
	Prop	Jets	Prop	Jets
150	1/4	3/4	1/2	1
210	1/4	1	1/2	1
240	1/2	1-1/4	1/2	1
300	1/2	1-1/2	1/2	1
400	1	2	1/2	1
500	1-1/2	2-1/2 to 2-3/4	1/2	1
600	1-3/4	3-1/4	1/2	1

Fixes

The fix symbol on plots for friendly aircraft consists of a small circle with a dot in the center. The fix symbol for enemy aircraft is a small "x." A solid line, touching neither fix, is used between fixes. When a new fix is obtained, the present DR track is abandoned and a new DR track is commenced from the new fix.

Orbits

There are times when the CAP is directed to circle or orbit in a given position instead of flying on an assigned course. The air controller can order two types of orbits, the simple or the figure eight orbit.

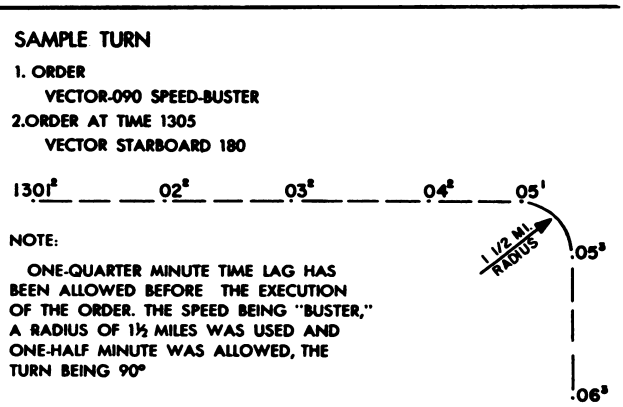

Figure 15-7.—Dead reckoning a turn.

The simple orbit is dead reckoned around one complete circumference at saunter speed. The radius of the circle is 3 miles (6 miles in diameter) and consumes about 6 minutes. After one complete orbit, when a new vector is given the fighters, start dead reckoning the fighters from the center of the orbit.

Figure 15-8 is an example of a DR plot of a sample orbit and turn.

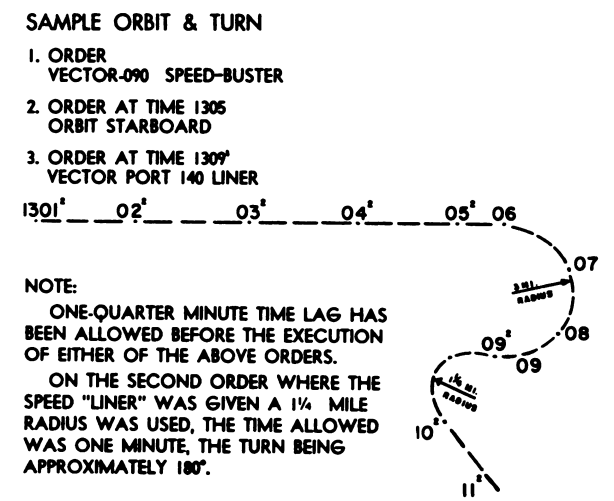

Figure 15-8.—Dead reckoning an orbit and turn.

Study figure 15-9. The figure eight orbit is dead reckoned through one complete figure at saunter speed, and also requires 6 minutes to complete. The long axis of a figure eight orbit is approximately 6 miles and is perpendicular to the previous line of travel. Both orbits can be directly across the line of travel, entirely to the right, or entirely to the left. After one

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complete orbit, the DR starts from the center of the figure eight as in the case of the simple orbit.

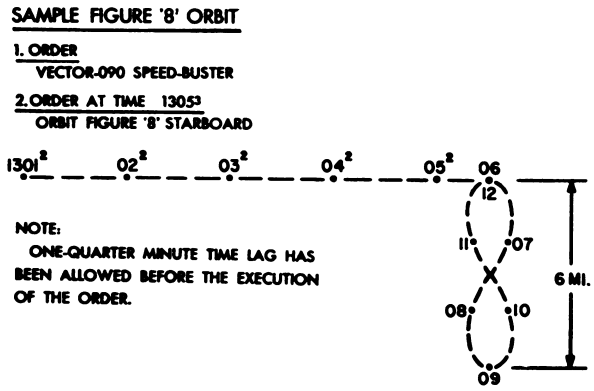

Figure 15-9.—Dead reckoning the figure "8" orbit.

Change of Altitude

When DR-ing planes that are climbing, the track is advanced at saunter speed. When DR-ing planes that are descending, the track is advanced at GATE speed.

CONVERSION PLOTTING

There are various methods of making position reports in use today in air defense operation. Some of these methods are: (1) latitude and longitude, (2) grid systems, and (3) bearing and distance from own ship, another designated ship, or from a specified point.

Any of these three basic methods may be used to report positions, but each of the methods has several variations. Also, each has advantages and disadvantages. The OTC must specify the method which is most suitable in a particular situation, and normally the method to be applied is set forth in the operation order.

The use of these systems require a means of converting coordinate information so that range and bearing information of own ship's radar may be translated to the task group coordinate system, and raid reports received in the task group's coordinate system may be translated to polar coordinates for gunnery target designation.

The conversion plot is not necessarily a separate plot but is usually combined with or superimposed upon another plot. In many ships, because of personnel and space limitations, conversion is done on the summary plot.

LATITUDE AND LONGITUDE METHOD

The system of geographic coordinates expressed in latitude and longitude is used by the services as world position reference system, and all maps and charts produced by and for the services include geographic references in squares. To use the latitude and longitude system requires too much time in converting; it is, therefore, not used in raid reporting very often. For example, a raid reported by a ship using the latitude and longitude method must be plotted on a chart and then your position must be plotted before the range and bearing of the target from you can be determined.

GRID SYSTEMS

Grid systems are just another version of reporting by latitude and longitude. Grid systems are used to simplify the exchange of positional information between ships and aircraft and have special advantages in certain situations. The grid systems are discussed in detail in *Radarman 3 & 2, Vol. 2* and *NWP 31*. Therefore, not much will be said about them here. However, they are used a lot in present air defense operations, especially when picket ships and other ships are dispersed over a large area.

POSITION REFERENCE SYSTEMS

When operating near land, bogey reports are often converted to some central geographic point. This is particularly true during an amphibious operation when hundreds of ships are concentrated in an area. You might have no idea of the contact's location, if the report were given at a range and bearing, from another ship. On the other hand, you could immediately translate a report that placed the bogey at a range and bearing from a reference point.

REPORTING FROM OWN SHIP

Suppose you pick up a raid bearing 010-50 and you want to make a warning net report to the other ships in the area. All the ships probably won't know your ship's exact location, but they should know where the flagship is. Consequently, there are certain times when you should report the raid in terms of its range and bearing from the flagship, and not from your own ship. The process used to make the change in the bogey's range and bearing is called conversion plotting. Normally, the only time you

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make reports directly from your ship, is when you are steaming along in a tight formation and the distance between ships is negligible.

HOW TO CONVERT A RANGE AND BEARING

The simplest and quickest technique is the parallelogram or eye method. By using this method you can use your air plot to measure bearings and ranges from all different reporting positions. Instead of moving the plotting board, the point is read from one position, and moved so you can read it from any other position by use of an imaginary parallelogram.

Study figure 15-10 carefully. A represents your own ship, and B the flagship, bearing 070-30 miles. X, bearing 010-50, is picked up and plotted by your ship. The bearing and range of bogey X from your own ship would, of course, be computed from a line drawn along AX. Your problem, however, is to report the bogey's bearing and range from the flagship, B. To do this quickly, take your pencil and lay it along the line BX and move it toward the center so that B traces along the line BA. When point B coincides with A, you have your relative position line, AC. This line indicates the bearing of the bogey from flagship B, 333°. The distance to the bogey is the same as from BX, 43 miles.

Conversely, the bogey may be reported to you in its position from the flagship B. In this case you would take the range and bearing received and lay it off from A, forming line AC. This line, when transferred to the flagship so that it traces along line AB, gives the position of the bogey. When point A coincides with B, you have the relative position line, BX, with the bogey being positioned at X.

Using the grid system to convert is not as difficult as the case just explained. As you can see in figure 15-1, the grid squares are made by stretching strings in front of the summary plot. When a ship reports a target in the grid system, the plotter will plot them as received, as grid coordinates. The center of the board represents your ship. Ranges and bearings can be read directly.

AA COORDINATION PLOT

The expanded scale of the summary plot and the need for a display of close-in air and surface tactical situation has led to the increased use of an AA coordination plot in CICs. This plot is a display of air and surface information within a certain range, usually 50 miles, with an expanded scale (1 circle equals 5 miles) on a standard 36" vertical plotting board. The right-hand plotting board in figure 15-1 shows what the board looks like. The illustration shows a grid system superimposed over the polar coordinate markings. The symbols and abbreviations used on the summary plot are the same used on the AA coordination plot. Included on this plot should be:

1. All unidentified air contacts.
2. All friendly air contacts.
3. All friendly surface contacts.
4. Target designation sectors.
5. Special watch zones.
6. Air raid warnings.
7. Missile and AA gunfire restriction conditions.

The AA coordination plot serves three primary purposes: (1) enables the gunnery liaison officer to correlate information received from other sources with his target designation system scope, (2) simplifies the coordination of CAP, missiles and AA gunfire, (3) permits the Task Group AA Coordinator to control main body AA fire.

AIR STATUS BOARD

A fixed arrangement of the information placed on the air status board has not been established, since it is preferable to arrange the information as required in each individual ship. (Fig. 15-11 is an example of a typical air status board.) The effectiveness of the board depends on whether the information plotted is accurate and current, on the clarity of the plotting and printing, and on the accessibility of the board to the persons who are required to use it.

The air status board recorder usually monitors the FAD (fighter air direction) net so he can hear the conversation between the air controller and the CAP pilots.

ABBREVIATIONS USED ON AIR STATUS BOARD

Because of the large amounts of data which sometimes must be entered upon the air status board, many items commonly used have been given standard abbreviations in order to save space and for clarity.

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Principal Abbreviations

Meanings of some principal abbreviations used on an air status board like the one shown in figure 15-11 are:

Abbreviation	Meaning
Div.	Division call—for example, BLACK 1.
Order	Instruction to fighters—for example, P 270 (Vector Port 270).
SP	Speed—for example, BU (Buster).
AG	The angles to which the fighters have been ordered.
ETRA	Estimated Time Reach Angles. (The time at which the fighters will reach the angles to which they have been ordered.)
Time	The time at which the order is given.
Wind	The direction from which the wind is blowing and the velocity of the wind in knots.
Var.	Variation.
Sun (Moon)	The bearing and elevation of the sun (or moon).

Order Abbreviations

A great variety of orders are entered in the order column. The most common abbreviations for standard orders entered on the status board are:

Order	Status Board Entry
ORBIT BASE	ORAS
ORBIT 10 MILES EAST	OR 090-10
ORBIT PORT	OR P
ORBIT POINT KILO	OR K
ORBIT FIGURE-OF-EIGHT STARBOARD	OR F8S
VECTOR 180	180
VECTOR STARBOARD 080	S-080
PORT 20 (Following preceding order)	P 060
VECTOR HARD PORT 300	HP 300
SCRAMBLE	SC
PANCAKE	PK
RESUME 090	RM 090
TALLYHO	TH
SAUNTER	SA
LINER	LI
BUSTER	BU
GATE	GA
SCRAMBLE GATE ANGELS 20	X20
ANGELS 10	10

INFORMATION CONTAINED ON AIR STATUS BOARDS

Much of the information contained on the air status board can be obtained from the flight schedule. This schedule is published daily by the aircraft carriers.

Air status boards are usually arranged in the following categories; fighter aircraft screen, search and patrol aircraft, attack aircraft, depending on the types of ships and mission. The information displayed on these boards is as follows:

FIGHTER AIRCRAFT

1. Tactical calls of all available fighter planes.
2. Divisions airborne.
3. Present fuel, ammo., and oxygen.
4. Time of takeoff.
5. Altitude information.
6. Station mission.
7. Radio channel.
8. IFF mode.
9. Controlling base.
10. Last order.
11. Magnetic variation.
12. Homing guards—YE homing beacon with compass bearings inscribed.
13. VF (fighters) on board and their condition of readiness.
14. Range and bearing of nearest land. Range and bearing to nearest land is to be kept up-to-date with new information every 30 minutes.
15. Range and bearing of enemy base or force.
16. Surface winds and winds aloft.

SCREEN, SEARCH AND PATROL AIRCRAFT

1. Screen, search or patrol plan.
2. Composition of the screen, search or patrol unit.
3. Progress of the unit.

ATTACK AIRCRAFT

1. Composition of the attack group.
2. Mission.
3. Progress to and from target.

PLOTTING ECM INFORMATION

Passive ECM information is displayed on three boards. These are an ECM status board, an ECM tracking plot and the summary plot.

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ECM STATUS BOARD

As discussed in a previous chapter, the purpose of the ECM status board is to display radiation characteristics of important enemy signals that may be intercepted. It is also used to display reported data as occurring plus indication of status and action taken as a result of such reports.

In addition, complete, up-to-date listing of all friendly and known enemy electronic equipment should be kept readily available to ECM operators.

ECM TRACKING PLOT

Any horizontal plotting surface of sufficient size with adjacent communication facilities may be used for this plot.

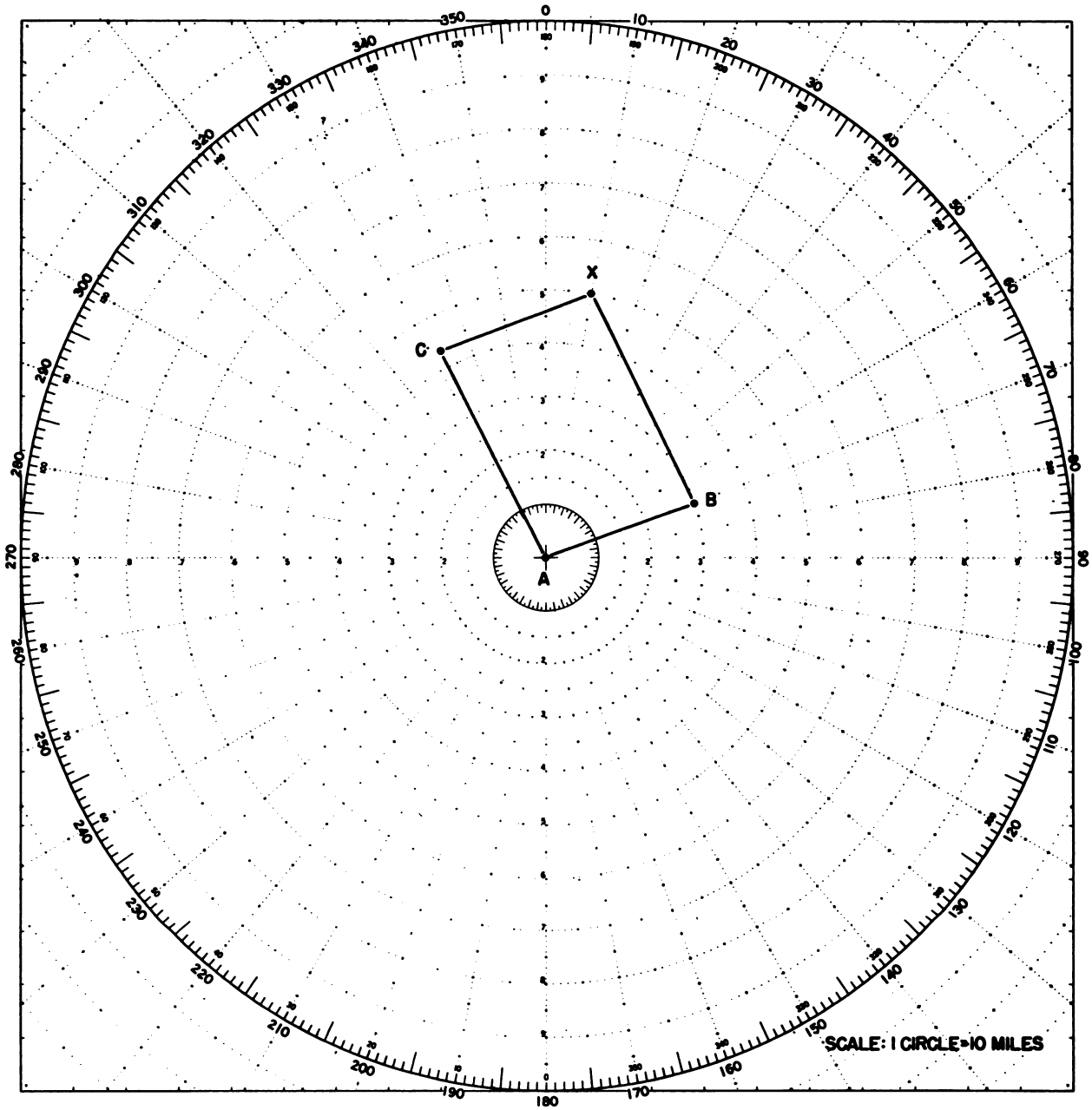

Figure 15-10.—Conversion plotting.

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The DRT is usually used for ECM plotting, but may be done as easily on the chart desk. If the DRT is used, the following procedure should be followed:

1. GEOREF coordinates are drawn on the underside of the glass with a grease pencil. Consult *Radarman 3 & 2, Vol. 2* or *NWP 31* to determine how to make the GEOREF. A scale of 8 or 10 miles to the inch is recommended.
2. A sheet of tracking paper is placed under the glass in order to diffuse the light.
3. Own ship's position and other ship's positions are plotted on the DRT and dead reckoned every 15 minutes.
4. ECM bearings are plotted on the DRT using the parallel motion protractor.
5. If the signal is continuous, bearings should be reported every 3 minutes, or other prescribed time intervals, by the ships holding contact.
6. Course and speed of the aircraft may be estimated by use of the parallel motion protractor.
7. Fixes obtained in this manner are then relayed to the summary plot by sound-powered phone.

SUMMARY PLOT ECM INFORMATION

ECM information should be displayed on the summary plot. Two types of information should be displayed.

1. Early warning information. For example, the initial bearing of the contact and its frequency.
2. Tracking information. For example, a fix relayed from the ECM tracking plot and ECM officer's evaluation of the type of emission intercepted.

STRATEGIC PLOT

Another plot of great importance used in air defense is the strategic plot.

The strategic plot is a large area geographic display on which is plotted information on the position, movement and strength of own and enemy sea, land, and air forces within a pre-

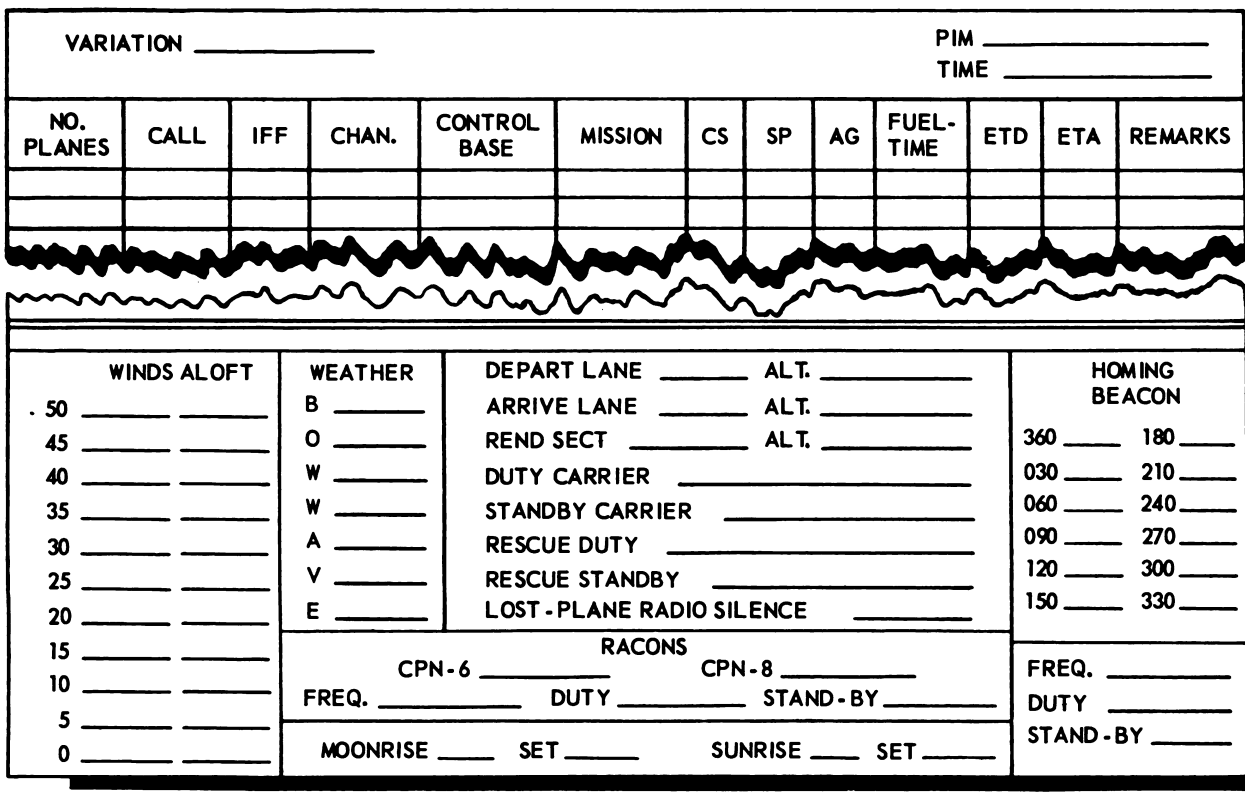

Figure 15-11.—Air status board.

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scribed area of operations. This display is maintained on hydrographic charts of suitable scale; information for it is derived from operation orders and plans, intelligence reports and reconnaissance.

It includes the location of own and enemy airfields, submarines, submarine havens and lanes, enemy surface dispositions, enemy bases, minefields and other strategic data which may at any time influence the over-all tactical situation. Such a plot is particularly useful in CIC in connection with recommendations relative to planning future actions and movements of a tactical nature.

QUIZ

1. What is the objective of air plotting?
2. Although the summary plot is primarily a picture of the air situation, what other information is displayed on it?
3. What symbol represents an unidentified aircraft (bogey)? An identified enemy aircraft (bandit)?
4. What is the purpose for using estimated position arcs?
5. How are split raids numbered?
6. Why is it necessary to know the variation of the location of your ship, in connection with DR plotting?
7. What must the plotter do to convert magnetic headings, ordered by the air controller, to true headings?
8. Who specifies the method to be used in reporting positions of enemy raids and where can you normally find this information?
9. What is the purpose of a reference point in conversion plotting?
10. What is the quickest technique for conversion plotting?

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CHAPTER 16

MANEUVERING BOARD

FURNISHING TACTICAL INFORMATION

The primary responsibility of CIC is to inform command on matters affecting the tactical situation. CIC accordingly furnishes conn with all available information on all contacts within radar range. To do this, CIC personnel utilize every available device—radar, PPI repeaters, DRT, surface plot, and the maneuvering board. Through these devices they obtain the required information on surface contacts such as: course, speed, and closest point of approach. CIC is also responsible for furnishing solutions to station-taking and interception problems.

As stated in chapter 14, most of the problems CIC is required to solve can be done on the surface plot and DRT. However, before you will be able to do this properly you must know how to use the maneuvering board.

This chapter deals with two types of maneuvering board problems. The course and speed problem, which is the basic problem for all maneuvering board problems. A complete understanding of this problem will make advanced maneuvering board problems easier to learn. With this type of problem you are primarily solving for the true course and speed of the maneuvering ship as well as the closest point of approach (CPA).

The other problem is called a change of station. Where you know the true course and speed of the maneuvering ship. You solve for own ship's true speed and time to make the maneuver when course is given; own ship's true course when speed and time are given; course and speed when time is given.

Other problems such as determining the course and speed that your ship is required to steer to get a certain relative wind across the deck for launching aircraft and other more complex problems are covered in *Radarman 3 & 2*, Vol. 2.

THE MANEUVERING BOARD

The maneuvering board itself is nothing more than a compass rose, containing a NOMOGRAM, or combined speed, distance, and time scale. The maneuvering board is used to calculate the RELATIVE MOTION of ships moving or maneuvering in formation, and from his calculations, the Radarman is able to solve problems relating to distances, courses, and speeds required for various evolutions. Solution of maneuvering board problems is fairly simple when you understand the fundamentals of RELATIVE MOTION.

RELATIVE MOTION

Geographical motion is the motion involved in a change of position; as when a ship moves from point A to point B on a chart, or an automobile moves from New York to Kansas City. Relative motion, on the other hand, is the combined result of the geographical motion of moving bodies. For instance, suppose two ships sail from the same anchorage, one heading north, and the other east, and both making 20 knots. Disregarding set and drift (the amount each will be offset by wind or current), each will have a geographical motion of 5 miles in the first 15 minutes, but at the end of that time they will be 7.07 miles apart. Although each has traveled only 5 miles, their relative motion will be 7.07 miles. This is illustrated in figure 16-1. Notice that at the end of 30 minutes, each will have traveled 10 miles on their respective courses and the movement of relative motion (MRM) is 14.14 miles. At the end of 45 minutes the MRM traveled is 21.2 miles.

NAVIGATIONAL PLOT

Relative positions of ships in formation may be presented graphically by the navigational plot (DRT), and their DR positions run forward to show changing relationships. The navigational plot, however, does not usually present a good picture of changing conditions as they appear to

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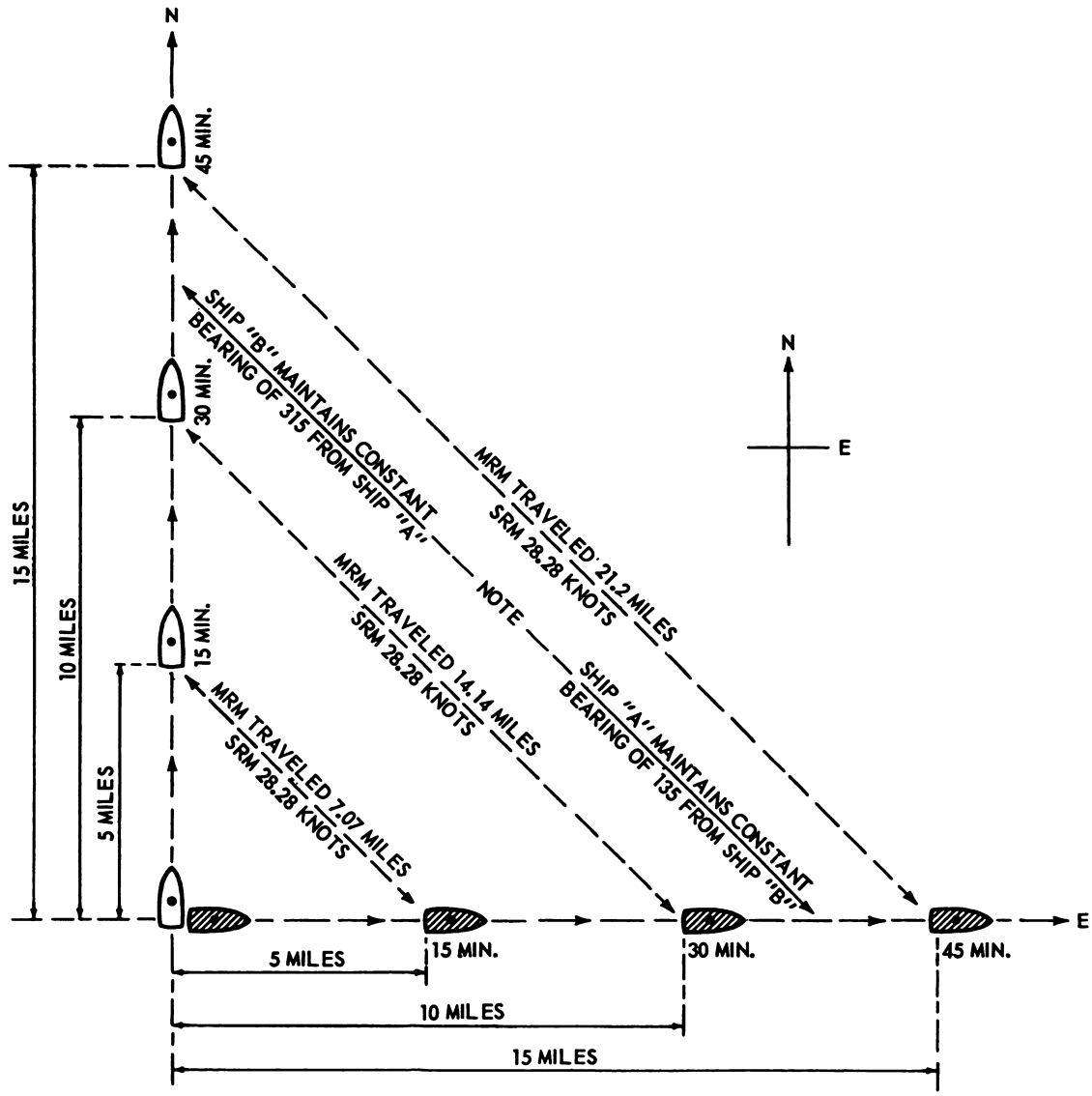

Figure 16-1.—Relative movement.

an observer on one of the ships, and changes of position calculated by this method frequently require trial-and-error solution.

RELATIVE MOVEMENT PLOT

By the RELATIVE MOVEMENT PLOT, not only actual motion, but motion relative to a moving point (relative motion) may be determined.

Relative motion may be more clearly understood if we use a common illustration of it. Assume that all ships in a formation are proceeding at the same speed along the same course, they remain stationary (relative to each other); in other words, they have no relative movement. If, however, one ship forges ahead or drops behind, then that ship has movement relative to the others, and they have relative movement to it, even though they remain on their former course and continue to run at the same speed.

Relative movement, then, OCCURS ONLY WHEN THE ACTUAL MOTIONS OF TWO OR MORE UNITS ARE NOT THE SAME.

Let us take a problem that is familar to you and discuss it in the language of relative motion. Look at figure 16-2. Ship A is steering 270° and

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making 25 knots. Ship B is 1000 yards astern, making 10 knots and also steering 270°. What happens as these two ships move along? As you know, the range between the two ships opens, and by subtracting 10 from 25, you know the speed at which the range opens. It is opening at the rate of 15 knots, or 500 yards a minute. At first, the distance between the two ships is 1000 yards. One minute later it is 1500 yards, and in another minute it will be 2000 yards. This change is the RELATIVE MOVEMENT. Relative motion is not concerned with ship A alone or with ship B alone, BUT WITH THE RELATIONSHIP BETWEEN THEM.

Consider relative direction first. What direction does the motion have? First, decide whose point of view you are going to take. Inasmuch as relative motion is the motion of one ship in relation to another, put yourself aboard one of the ships and judge the movement by relating it to your ship. In this example, consider the relative motion from the point of view of an observer on ship B.

Forget, for the moment, about the actual motion that is taking place and imagine that you are looking at the PPI scope on ship B. Forget that you are steering 270° and making 10 knots, and forget that ship A is really making 25 knots on a course of 270°. Just think about what is happening to the relationship between the two ships—that is, what is happening to the bearing and range of A from B.

As you observe the PPI scope, you would notice A's bearing is always the same—270°—but that the range is constantly opening at the rate of 500 yards per minute, or 15 knots. During this minute, the distance between the two ships changes by 500 yards. To state this more precisely, you can say that relative motion is in the direction of 270° or that the relative direction is 270°. The relative speed is 15 knots and the relative distance over the period of consideration is 500 yards.

Ship A would appear to move on a course of 270° and at a speed of 15 knots over a distance of 500 yards. The important word is APPEAR.

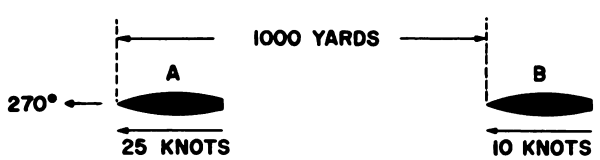

Figure 16-2.—Relative motion deals with the relationship between moving ships.

Ship A would appear to have this motion because you have judged it in the light of the relative motion between the two ships instead of the individual motion of each ship.

RELATIONSHIP OF RELATIVE MOVEMENTS TO NAVIGATIONAL PLOT

Consider another example, the case of two ships, one 2000 yards ahead of the other, and each sailing in different directions. Figure 16-3 shows ship A proceeding on course 000° at a speed of 15 knots, while ship B is on course 026.5° at a speed of 22 knots. When A is at A_1, B is at B_1: When A is at A_2, B is at B_2, etc. The full lines represent the navigational tracks of the ships. The bearing and distance at any time can be determined directly by measurement. Note that each position illustrated the bearing of B from A is exactly the reciprocal of A's bearing from B. (This is shown in both the tracks and the respective PPI scopes on board the ships.)

In figure 16-4, the various positions shown in the PPI scopes of figure 16-3 are plotted on a single scope for each ship. Note, that they form a straight line. It can be seen, that although ship B is actually on course 026.5°, its movement RELATIVE to A is in the direction 062°. Similarly, the direction of RELATIVE movement of A with respect to B is the reciprocal of this, or 242°, although A is on the actual course 000°.

The PPI scope permits visualization of relative movement, since the positions of the target ship on the scope are all relative to your ship. Hence, the motion observed on the PPI scope is RELATIVE MOVEMENT. ACTUAL MOTION IS SEEN ON YOUR PPI SCOPE ONLY WHEN YOUR SHIP IS STATIONARY. (If your PPI presentation has an input from the dead reckoning analyzer, however, this is not true. Then the picture presented on the scope will be a true geographic picture just like the DRT.)

PARTS OF THE RELATIVE MOVEMENT PLOT

The relative movement method consists of two distinct but related parts:

1. Relative plot.
2. Vector diagram.

The function of each line and point must be clearly understood, as well as its relationship to every other line and point, if problems are to be solved intelligently.

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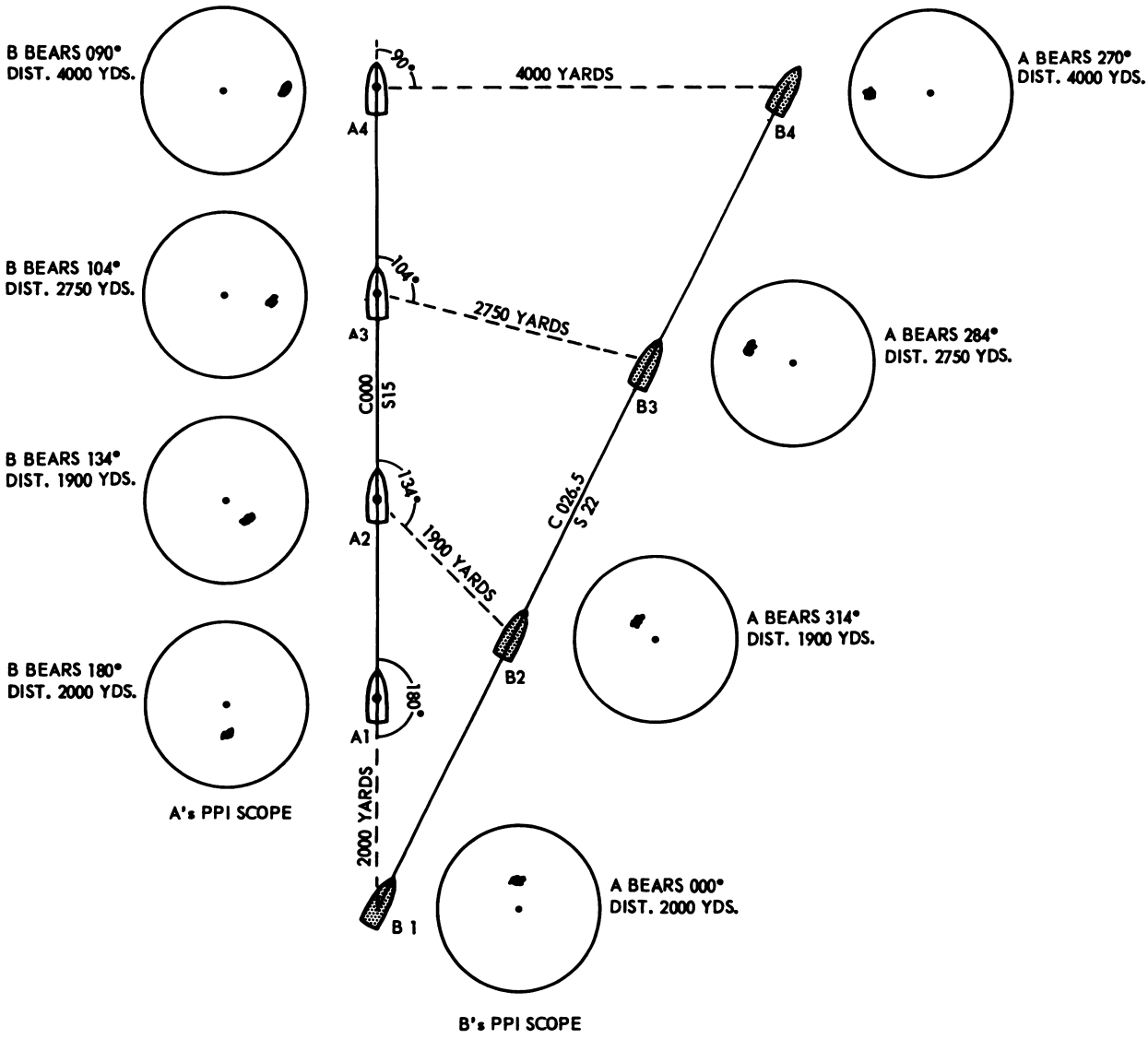

Figure 16-3.—Relative movement on a navigational plot.

RELATIVE PLOT

It will be noted in figures 16-3 and 16-4 that the ship on which the radar is mounted always remains at the center of the PPI scope. Therefore, in the relative plot we have the following rule.

THE SHIP WITH RESPECT TO WHICH RELATIVE MOVEMENT IS TO BE SHOWN REMAINS FIXED ON THE PLOT.

This ship, termed the REFERENCE SHIP, is placed at the center of the diagram and labeled R (fig. 16-5). Since you are usually interested chiefly in the position of other ships with respect to your own, it is preferable to designate your ship as the reference ship. It follows that any ship other than the reference ship will be shown in a different position on the plot, except in the special case of a ship on the same course and speed as the reference ship. Any ship other than the reference ship is called a MANEUVERING ship and is labeled M. Initial position labeled M_1 and its successive position M_2. Where more than two positions are of interest they are labeled M_3, M_4, etc.

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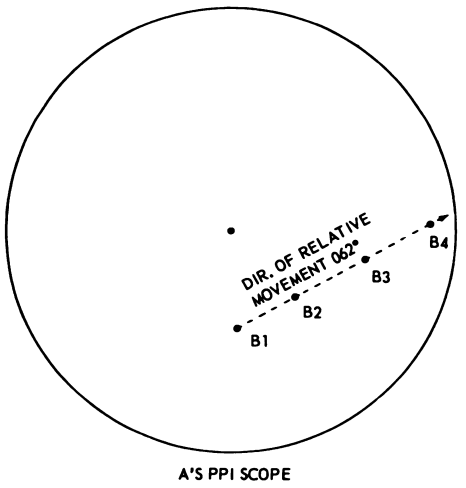

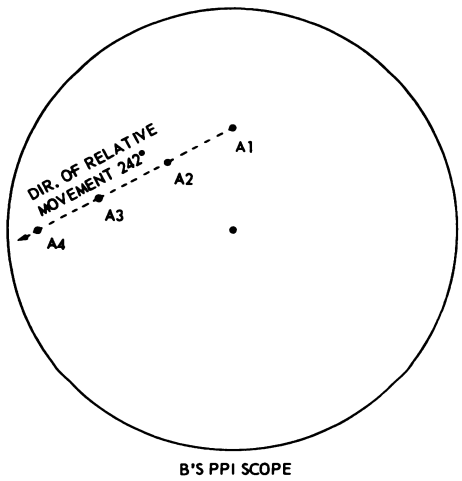

Figure 16-4.–Relative movement on a radar PPI scope.

Figure 16-5 illustrates the situation in figure 16-3, with A the reference ship and B the maneuvering ship. The line M_1-M_2, called the RELATIVE MOVEMENT LINE, defines:

1. Direction of relative movement of the maneuvering ship with respect to the reference ship.
2. Distance of relative movement (by its length). (This line gives no clue as to the heading or speed of the maneuvering ship, since the ship heads in the direction of travel through the water and not in the direction of relative movement.)

The RELATIVE MOVEMENT LINE INDICATES THE ACTUAL HEADING ONLY WHEN THE DIRECTIONS OF RELATIVE AND ACTUAL MOTION HAPPEN TO COINCIDE.

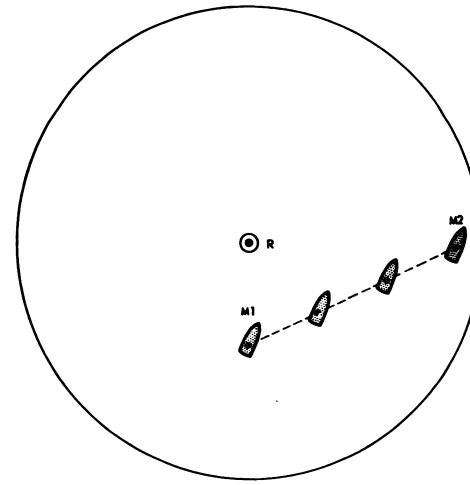

Figure 16-5.–Elements of a relative plot.

VECTOR DIAGRAM (SPEED TRIANGLE)

A vector is a line representing direction by the way it extends and magnitude by its length.

A vector diagram composed of three vectors representing the actual courses and speeds of two ships and the relative course and speed of one ship in relation to the other may be called a SPEED TRIANGLE.

The three vectors are labeled and represents the following: (illustrated in figure 16-6).

1. The er vector.
   a. ACTUAL COURSE of the reference ship, indicated by the direction of the line er.
   b. ACTUAL SPEED of the reference ship, indicated by the length of the line er.
2. The em vector.
   a. ACTUAL COURSE of the maneuvering ship, indicated by the direction of the line em.
   b. ACTUAL SPEED of the maneuvering ship, indicated by the length of the line em.
3. The rm vector.
   a. DIRECTION OF RELATIVE MOVEMENT or RELATIVE COURSE of the maneuvering ship with respect to the reference ship, indicated by the direction of the line rm.
   b. RELATIVE SPEED, OR SPEED OF THE MANEUVERING SHIP relative to the reference ship, indicated by the length of the line rm.

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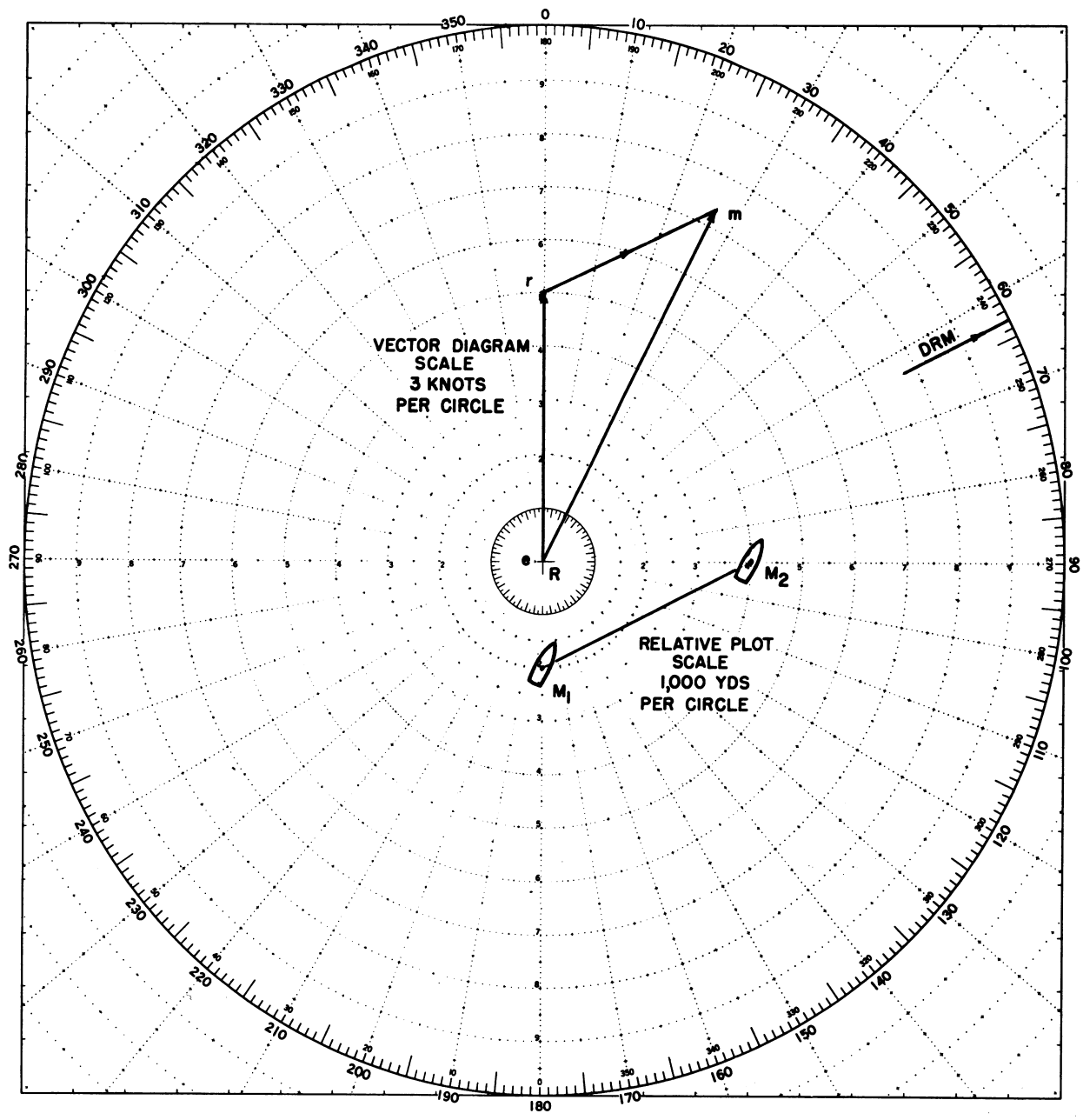

Figure 16-6.—The complete relative movement plot.

LABELS ARE IMPORTANT

You can see, then, that each line (or vector) represents both direction (course) and speed. The diagram must be properly labeled for correct interpretation.

USE OF THE MANEUVERING BOARD IN SOLVING PROBLEMS

The maneuvering board, or polar coordinate chart, is a special plotting sheet, which will help you in working problems involving relative motion. These charts (HO 2665a) are prepared by

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the Hydrographic Office and can be obtained in the same manner as any other chart.

Maneuvering boards are printed with radial straight lines (to aid in plotting bearings and courses) and concentric circles (to aid in plotting distance and speeds) similar to the surface plot you learned to use in chapter 14.

The major difference in the maneuvering board and the surface plot is that the maneuvering board has two sets of bearings printed along the outer circle. The outer set of numbers are true bearings and the inner set of numbers are printed as an aid in finding reciprocal bearings quickly.

Figure 16-6 shows a maneuvering board. Notice in the illustration that there are 10 circles. These circles are used in the same manner as those on the surface plot. They represent units of distance, and may be used to form a scale.

Ratio scales are provided on the left and right side of the maneuvering board for convenience in adopting a suitable reduction for the quantities involved in the problem at hand. (Fig. 16-8).

The numerical spacing on each scale is proportionate to that of the circle in the plotting area. When selecting one of these scales the distance of each circle must be amplified accordingly. For example, when using a 1:1 scale (circle spacing in plotting area) the 5 circle represents 5000 yards. If the 2:1 scale is used the 5 circle would then represent 10,000 yards (5000 x 2).

Ordinarily, the distance between circles on the maneuvering board will represent from 1000 to 5000 yards in the relative plot, and 1 to 5 knots in the vector diagram. You may choose any scale which will be adequate and convenient to include all required ranges and speeds within the ten concentric circles on the board.

To determine what range scale to use is very easy. You know there are 5 different scales, so therefore, the maximum range for these scales would be 10,000 yards for the 1:1, 20,000 for the 2:1, etc. Thus, if you obtained a range to a contact of 14,000 yards, you would use the 2:1 scale, since this range falls between 10,000 and 20,000 yards. The following table will assist you in determining the range scale.

From	To	Scale
0 yards	10,000 yards	1:1
10,000 yards	20,000 yards	2:1
20,000 yards	30,000 yards	3:1
30,000 yards	40,000 yards	4:1
40,000 yards	50,000 yards	5:1

As you will learn later in this chapter, it may be convenient to choose one scale for the relative plot and another for the vector diagram. (One represents distance and the other speed.) The same table can be used, except, where the table reads yards, change to knots and delete the last three zeroes. For example: 10 to 20 knots.

At the bottom of the maneuvering board is a NOMOGRAM. The nomogram affords a ready means of interconverting time, speed, and distance, and of solving graphically for any of these quantities when the other two are given.

Figure 16-7 is an illustration of these scales. The top line is the time line or logarithmic scale in minutes and the middle one is the distance scale. The numbers on the top of the distance scale give the distance in yards, and those below give the distance in miles. The bottom line is the speed scale and is given in knots.

The words RELATIVE or ACTUAL, used with the speed and distance scales, are included only to inform you that both relative and actual problems may be solved. If you use relative distance, the speed used must be relative.

The three scales are based on the formula DISTANCE = SPEED X TIME. They are so arranged that by marking off any two known values in this formula, and laying a straight edge through the points so marked, the correct value of the third quantity will be cut through the third scale.

For example: suppose you observe that a ship has traveled 1500 yards in 5 minutes. What is the speed?

Figure 16-7 shows the graphic solution to the above problem. On the time scale, 5 minutes was located, and on the distance scale, 1500 yards was located. A straight line is then drawn through these two points and extended across the speed scale. The speed scale is cut at 9 knots. That is the answer to the problem. In figure 16-7, if the distance is relative, then relative speed must be used to get a correct answer. Consider the simple example for adding algebraically—trying to add apples and oranges to get a single, whole number representing a single total. It can't be done—that is, you would have to qualify your answer to make it something in the order of "this many apples and that many oranges." The impossibility of such a mixture is the same as mixing relative and true values in the nomogram.

CLOSEST POINT OF APPROACH PROBLEMS

When the range, bearing, and composition of a radar—detected contact is sent to the bridge,

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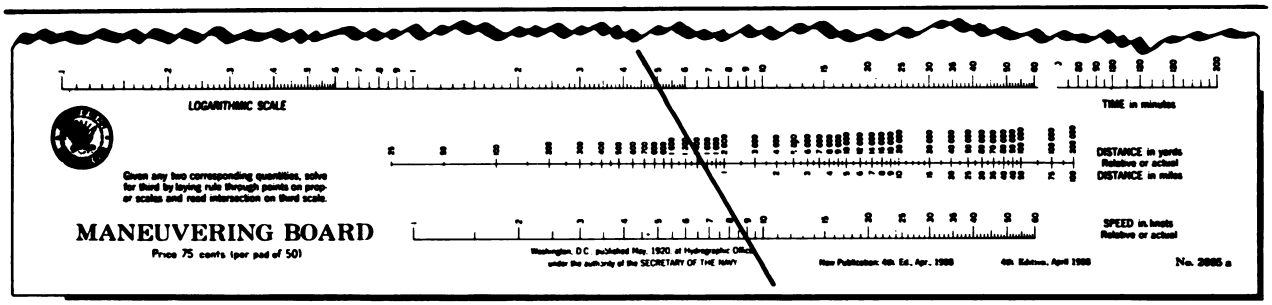

Figure 16-7.—Maneuvering board nomogram.

the OOD will expect information about course, speed, and CPA (closest point of approach) of the contact to follow shortly afterward.

CPA is the position of the contact at which it reaches its minimum range to your ship. CPA is expressed in bearing (true) from own ship, range (yards) from your ship, and the time it will reach that point.

On a maneuvering board or summary plot, the point and time of a contact's closest approach can be found before solving a vector diagram for the target's course and speed.

PROBLEM 1

SITUATION—Your ship is on course 300°, speed 15. See figure 16-8. At 0530 the surface search radar operator reports a surface contact at bearing 236°, 18,000 yards, closing. At 0531, it has closed to 17,000 yards, on bearing 235°. The radar operator continues to report ranges and bearings as follows: 0532-234/16,400, 0533-232/15,600, 0534-230/15,000, 0535-228/14,200.

REQUIRED—The following:

1. The direction of relative movement (DRM of the contact with respect to your ship).
2. The true bearing of contact when it reaches its minimum range from you.
3. The minimum range it will pass your ship.
4. The relative bearing of the contact when it reaches that point.
5. The speed of relative movement (SRM of the contact with respect to your ship).
6. The time the contact will reach that point.

SOLUTION—The first consideration in this problem, as with any maneuvering board problem, is the choice of scale to be used. Using our table as listed before, we find the contact's initial range is less than 20,000 yards and greater than 10,000 yards, therefore, the 2:1 scale is the most suitable one to fit the board and present the largest picture, thus more accurate solutions can be obtained.

HOW TO DETERMINE POINT OF CLOSEST APPROACH

Construct a track of the contact long enough to establish its M_1-M_2 line of relative movement. Extend this line across the maneuvering board. This is done by plotting all the ranges and bearings listed. Label the first plot M_1 the last M_2.

Next, determine the DRM (direction of relative movement) of the contact. The direction of relative movement is described by its degree of bearing. Notice in figure 16-8 that no degree markings are given along line M_1-M_2. To determine the direction of relative movement you must draw a line parallel to M_1-M_2 through the center of the maneuvering board. Extend the line in the direction of relative movement to the edge of the maneuvering board and read DRM on the bearing circle. Notice that the line parallel to the relative movement line crosses the bearing circle at bearing 083° in our illustration. Therefore, DRM is 083°.

The method of moving line M_1-M_2 over to the center is by use of a parallel ruler. Lay one edge along the relative movement line, M_1-M_2. Oftentimes you will have an erratic plot, in other words, the plots will not fall in a straight line. This is caused by the radar operator making an error of a couple of degrees or an error of a few hundred yards. The radar beamwidth has a contributing factor in bearing accuracy also. In case you have an erratic plot, lay one edge of the parallel ruler along the average or mean of the plots. Now "walk" the parallel ruler to the center of the board.

From the center of the board, drop a perpendicular to the extended relative movement line. The intersection of these two lines indicates the bearing and range of the closest point of approach.

In our example, a perpendicular to the relative movement line is made by adding 90° to the

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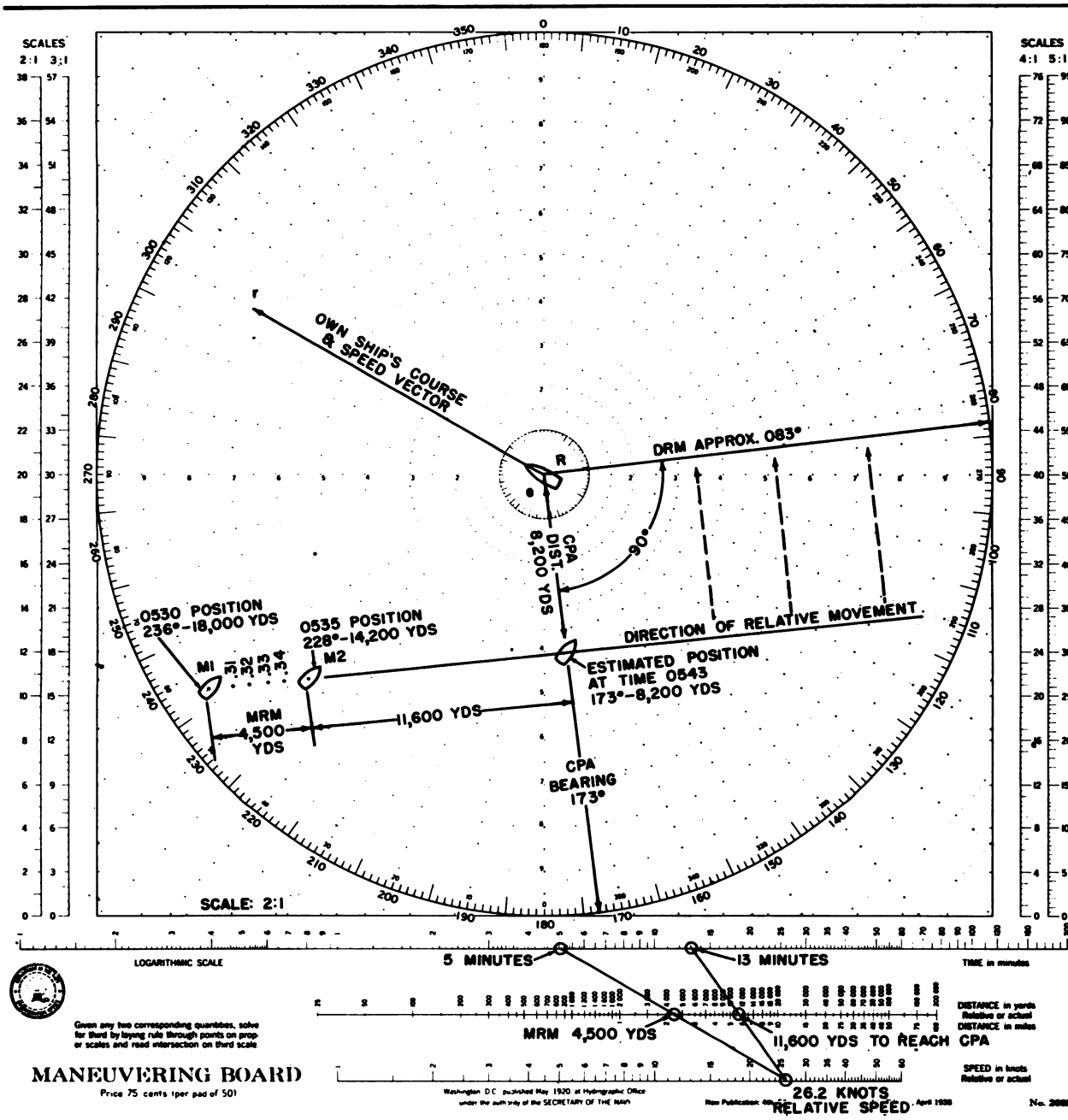

Figure 16-8.—Using the relative plot to find CPA.

DRM. Thus, 083° + 090° = 173°, the true bearing of the contact when it reaches its minimum range from us.

There are instances when you must subtract 90° from DRM rather than add 90°. In such cases, adding 90° will give the reciprocal of CPA. The only way to determine whether to add or subtract is to carefully observe your plot to make certain the bearing of CPA lies on the same side of own ship as the relative movement line.

Where the bearing line crosses the projected line gives the range to the point of closest approach. This range is measured from the center of the board, using the same scale (2:1) used to

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plot the positions of the contact. In the example, the range is approximately 8200 yards. This means that 8200 yards is the closest point to your ship the contact will come, provided neither ship changes course or speed.

Thus far, you know the range and the true bearing at which the contact will be closest to your ship. Occasionally, the OOD will ask for the relative bearing of this point. Using the formula you learned in chapter 14 (relative bearing of an object equals true bearing of the object minus ship's head) you can find the answer to the problem. In our problem we get a relative bearing of 233° (R).

HOW TO DETERMINE TIME OF CLOSEST APPROACH

To determine the time at which the contact will be at CPA, measure the distance from point M_2 to the point of CPA, and find the SRM (speed of relative movement) of the contact with respect to your ship by using the 3-minute rule, nautical slide rule, or the nomogram at the bottom of the maneuvering board. For the time being, we are concerned only with the nomogram.

With dividers, measure the distance the contact moved during the 5-minute interval between 0530 and 0535. This is abbreviated MRM (measurement of relative movement). In our problem we get a MRM of 4500 yards.

Now that two quantities are known, the third can be found by using the nomogram. First, locate 5 minutes on the TIME scale. Next, locate 5600 yards on the DISTANCE scale. Now draw a straight line from point-to-point extending the line through the SPEED scale. Where the line cuts the speed scale indicates the SRM of the contact. Notice in figure 16-8 we get a SRM of 26.2 knots.

As you know, the nomogram at the bottom of the maneuvering board is based on the fact that given any two corresponding quantities, the third can be solved for by laying a straight edge through points on proper scales and read at the intersection in the third scale. So to find TIME you already know the SPEED (26.2), the other quantity is DISTANCE. With dividers, measure the relative distance the contact has to travel before reaching CPA. This is approximately 11,600 yards in the example. By performing the above instructions we get an answer of 13 minutes. Thus, the contact will be at CPA in 13 minutes or at time 0543.

The CPA and time of CPA problems are common types which you will be required to work many times while standing watch in CIC. Most of the time they will be worked on the surface plot. Since the surface plot does not have a nomogram on it you will be supplied with a nautical slide rule. The nautical slide rule is used in the same manner as the nomogram, and in many instances easier to use.

Since the nautical slide rule is used in the same manner as the nomogram using the same principle, no more will be said about it in this text. If you have any doubt about using it, be sure to ask your leading Radarman to give you instructions for the use of it.

The 3-minute thumb rule is another method of solving for relative speed. Its use eliminates your referring to the nomogram or the use of a nautical slide rule for relative speed solutions, thus saving you considerable time.

This rule is based on the number of yards the contact travels in 3 minutes. The reasoning behind the rule is simple:

1. One knot equals 1 nautical mile per hour.
2. One knot equals 2000 yards per 60 minutes.
3. If 1 knot equals 2000 yards per 60 minutes, then, reducing the distance traveled in 3 minutes, we find that a ship will cover a distance of 100 yards.

$$\frac{3}{60} \text{ or } \frac{1}{20} \times 2000 = 100 \text{ yards.}$$

4. Therefore, for each 3 minutes of travel, each knot of speed represents a distance of 100 yards.

Thus, if a ship travels 1200 yards in 3 minutes, its speed will be 12 knots because there are 12 units of 100 yards, in other words, to find speed, divide the distance run in 3 minutes by 100.

Dividing by 100 is easy too. All you have to do is point off, or drop two places from the right-hand side of the number you're dividing. For example, 6200 divided by 100 equals 62, and 2330 divided by 100 equals 23.3.

The 3-minute rule can be summarized into three short steps:

1. Determine the distance in yards traveled by the target in 3 minutes of time.
2. Point off two places.
3. Result is target's relative speed in knots.

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Normally, you need 4 plots to get a fair CPA and time of CPA solution. You should check the solution periodically, approximately every 3 minutes, to see if the solution is still correct, for it must be remembered that any change of course and speed of either your ship or the other ship, the CPA will change.

Before we go any further with the maneuvering board, let's make sure you understand the relative plot and the information that can be obtained from it.

The following problems are designed to exercise your knowledge and understanding of relative motion and show the manner in which relative motion is indicated in the solution of a maneuvering board problem.

Check your answers against those at the end of the closest point of approach problems section.

CPA EXERCISE PROBLEMS

PROBLEM 1

SITUATION—Your ship is on course 180°, speed 12 knots. A DD 7000 yards distant from you on your starboard beam has been ordered to a new station 7000 yards away from you on bearing 045° (T).

REQUIRED—

1. What is the DRM?
2. If the DD uses a course of 140° to make the maneuver, what will be the target angle of the DD when he is ahead or astern?
3. Range at CPA?
4. The relative bearing of the DD at CPA?
5. The true bearing of your ship from the DD at CPA?
6. The target angle at CPA?

PROBLEM 2

SITUATION—Your ship is on course 180°. A DD has been keeping station on your ship, its station has been 18,000 yards from you on bearing 130°. The DD is ordered to move to a new station 14,000 yards from you on bearing 020°.

REQUIRED—

1. What is the DRM?
2. At the closest point of approach, what will be the range of the DD from your ship?
3. The true bearing of the DD at CPA?
4. What is the relative bearing of the DD at CPA?
5. If the DD uses a course of 270° to make the maneuver, what will be the target angle when the DD reaches CPA?
6. What will be the true bearing of the DD when he is broad on your port beam?
7. What will be the true bearing of your ship from the DD at that time?
8. The target angle of the DD?

ANSWERS TO CPA PROBLEMS

PROBLEM 1	PROBLEM 2
1. 067°	1. 340°
2. 040°	2. 9000 yards
3. 2700 yards	3. 070°
4. 157°	4. 250°
5. 157°	5. 340°
6. 017°	6. 090°
	7. 270°
	8. 000°

COURSE AND SPEED PROBLEMS

Some of the problems involved in the movement of ships in formation are fairly simple of solution. If the simple problems are thoroughly understood, the more involved ones become easy, for they are composed of several simple parts.

PROBLEM 1

Determining a contact's course and speed. See figure 16-9.

SITUATION—Your ship, the USS *Saratoga*, is on course 010°, speed 15 knots. At time 0440, your radar operator reports a surface contact on bearing 340°, range 20,000 yards, closing. By 0441 the contact has closed to 341°, range 19,300 yards. Your radar operator continues to give ranges and bearings to the contact each minute, as follows: 0442-342/18,000, 1443-343/17,500.

REQUIRED—The bridge acknowledges your report of the contact, and wants to know:

1. Contact's course.
2. Contact's speed.
3. Whether the contact will cross *Saratoga's* bow.
4. The bearing of CPA.
5. The range of CPA.
6. The time of CPA.

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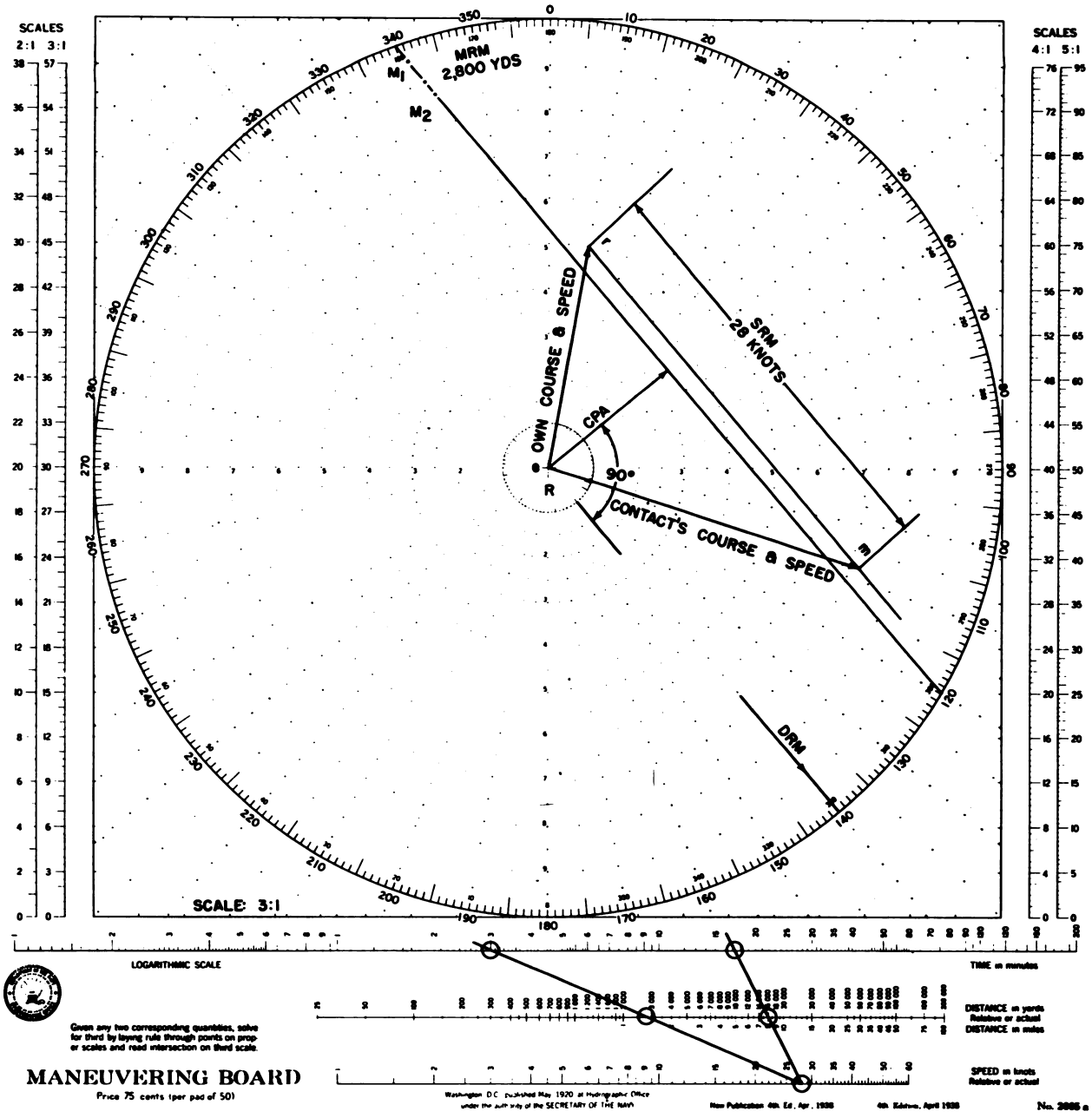

Figure 16-9.—Contact's course and speed problem.

SOLUTION—Be sure to "read the problem" carefully and understand it before you proceed with the solution. Check all answers. Determine the range scale and speed scale to be used. The 2:1 scale for distance and 3:1 scale for speed (for accuracy) are the best for this problem.

1. Lay off your ship's speed vector e-r on 3:1 speed scale from center of maneuvering board.

2. Lay off the bearings and ranges to the contact from center of maneuvering board and label plots M_1-M_2.

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3. In this particular problem, the plots run from time 0440 to time 0443, or a 3-minute plot. Because of the human element involved and possible mechanical error, each plot will not necessarily fall on a straight line. Therefore, a mean, or average, line must be drawn, going through as many plots as possible. This line, with the origin at earliest plot, becomes the DRM.
4. Transfer the DRM line to center of board and read the relative direction of movement on the compass rose. Figure 16-9 shows a DRM of 140°. Then transfer this DRM line and extend it from the head of your ship's speed vector e-r in the direction of relative motion.
5. Measure the distance MRM from plot at 0440 to the plot at 0443, or distance of line M_1-M_2. Our MRM is 2800 yards.
6. Determine the SRM by using the nomogram at bottom of maneuvering board. On the time line locate 3 minutes. On the distance line locate the distance the contact moved in 3 minutes (2800 yards). Draw a straight line through these two points and where it cuts the speed line indicates the SRM, 28 knots.
7. The necessary information is now complete to determine point "m" in vector diagram. Spread your dividers to a length of the SRM. Be sure to use the same scale as you did for the e-r vector. Place one point of dividers on point "r" and swing an arc in direction of DRM. Where the arc cuts across the DRM line indicates the position of point "m."
8. Read contact's course, e-m, from the compass rose, and contact's speed from the length of vector e-m. Our solution shows the contact on course 108° at a speed of 21.3 knots.
9. To determine whether or not the contact will pass ahead or astern, merely extend the DRM line in the direction it is moving relative to your ship from the last plot. If this extended DRM line crosses your course line, then obviously the contact will pass ahead of your ship, on the bearing 010°, or dead ahead.
10. In order to ascertain the bearing, range and time of CPA, proceed as with any CPA problem. Project the DRM line from last plot across the maneuvering board. Drop a perpendicular to this line. It is more convenient to subtract 90 from the DRM (140) in this problem. The CPA bearing in the problem is 050°.
11. Range to CPA is read from center of the maneuvering board out to the projected DRM line along bearing 050°. Be sure to use the same scale that was used for plotting positions M_1-M_2. Your answer should be 7000 yards.
12. The time of CPA is determined by measuring the distance from last plot to CPA. Our solution is 16,000 yards. The nomogram can now be used to find time. You already know the SRM from step 6 (28 knots). Thus, if the contact must travel 16,000 yards at a relative speed of 28 knots, it will arrive at that point in 17 minutes or at time 0500.

PROBLEM 2

Determining the required course or speed of the maneuvering ship. See figure 16-10.

SITUATION—The formation is on course 020°, speed 12 knots. You are on board the flagship. Cruiser A is 9 miles ahead of you.

ORDER—Cruiser A takes station on port beam of the flagship distance 7 miles.

REQUIRED—

1. The direction of relative movement (DRM of cruiser A with respect to your ship).
2. Cruiser A's course at 18 knots.
3. Cruiser A's course at 12 knots.
4. Cruiser A's speed if she steers 295°.
5. Cruiser A's speed if she steers 350°.

SOLUTION—Recommend using a scale of 2:1 in knots and 1:1 in miles.

1. Draw vector e-r to represent the true course, 020°, and speed 12 knots, of your ship.
2. Locate M_1 and M_2 and draw the relative movement line. To locate these points, determine first, the true bearing on the maneuvering ship from the reference ship at the beginning and end of the maneuver. Thus, if cruiser A is ahead of you at the start of the maneuver, and you are on course 020°, her true bearing from you is 020°. Her distance is 9 miles as given. M_2 is on your port beam, or at a relative bearing of 270°, or 290°(T), and the distance is 7 miles as given. Place an arrowhead on the relative movement line to indicate that the direction is from M_1 to M_2. The direction of this line may be determined by transferring it parallel to itself

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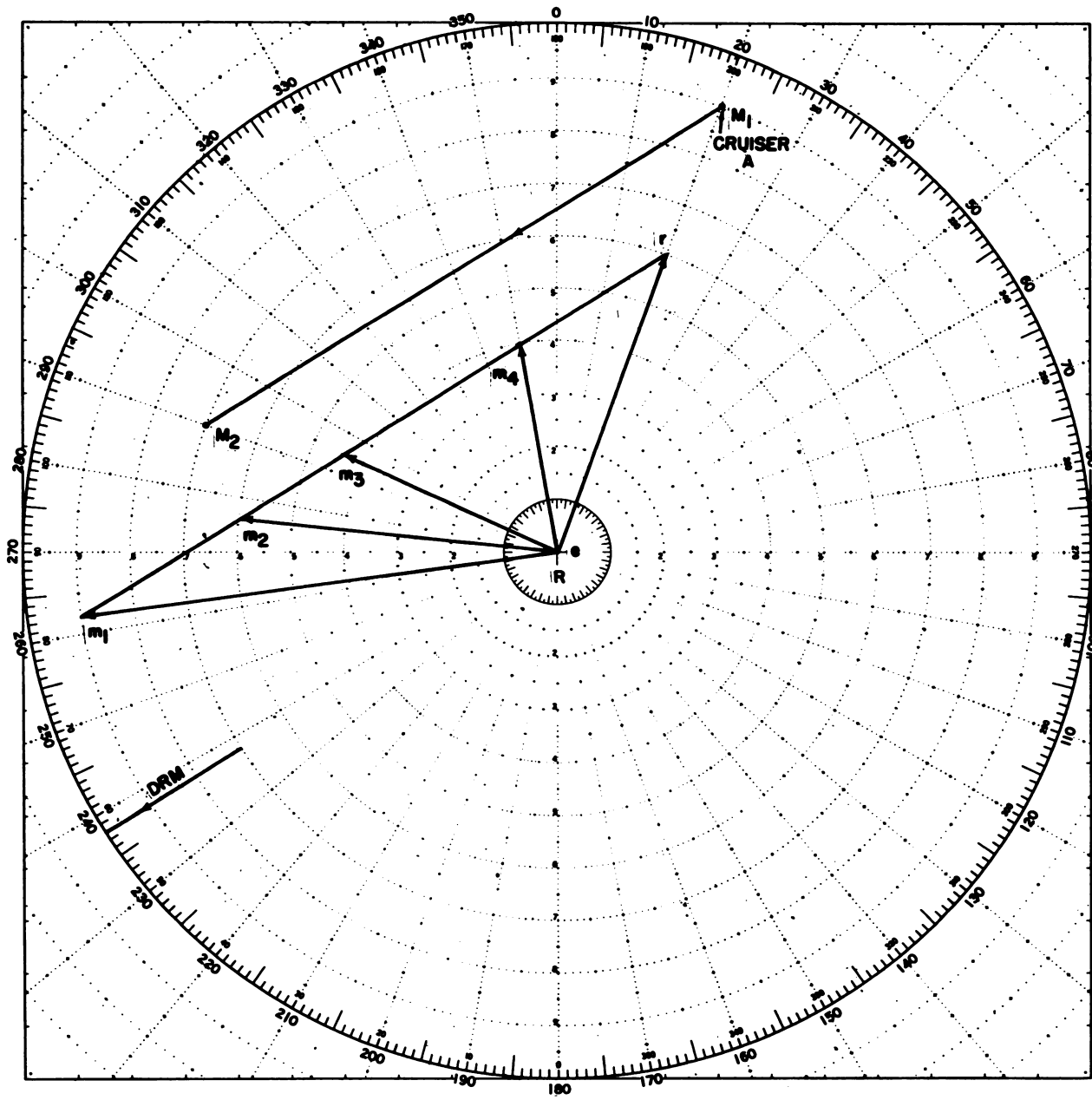

Figure 16-10.—Determining the required course or speed of the maneuvering ship.

to the center of the diagram, using the diagram as a compass rose.

3. Draw vector r-m, parallel to M_1-M_2. Begin this line at r, and continue it until it intersects the 18-knot speed circle (circle 9 at 2:1 scale).
4. Complete the speed triangle by drawing vector em_1 from the center of the diagram to m_1. The direction of this line represents the course required to produce the desired DRM at a speed of 18 knots.
5. Draw vector em_2 from the center of the diagram to the intersection of the rm_1 vector with the 12-knot circle.
6. Draw vector em_3 in the direction 295° from the center to its intersection with rm_1. The length of this line represents the true speed at course 295°.

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7. Draw vector em_4 in the direction 350°, determining the speed as in step 6.

Any of these combinations of course and speed of cruiser A, and others that might be chosen in a similar manner, will produce the desired relative movement.

Check your plot against figure 16-10. The answers are:

1. DRM 238°.
2. Course 262°.
3. Course 276°.
4. Speed 8.8 knots.
5. Speed 8 knots.

PROBLEM 3

Determining the required course or speed of the reference ship. See figure 16-11.

SITUATION—The formation is on course 020°, speed 12 knots. You are 9 miles ahead of the flagship.

ORDER RECEIVED—Take station on port beam of the flagship, distant 7 miles.

REQUIRED—

1. What is the flagship's direction of relative motion with respect to your ship?
2. Your course at 18 knots.
3. Your course at 12 knots.
4. Your speed if you steer 295°.
5. Your speed if you steer 350°.

SOLUTION—Use a scale of 2:1 in knots and 1:1 in miles.

1. Draw vector em, the true course, 020°, and speed, 12 knots, of the flagship.
2. Locate M_1 and M_2 and draw the relative movement line. If you are ahead of the flagship, your relative bearing from her is 000°, and your true bearing 020°. Her true bearing from you is the reciprocal of this, or 200°. Hence, M_1 is located on the 9-mile circle in direction 200° from the center. Similarly, when you are on the flagship's port beam, your relative bearing from her is 270°, and your true bearing 290°. Hence, her true direction from you is 110°, the reciprocal. Note, that true direction is determined before the reciprocal is taken. The DRM can now be determined by measurement.
3. Draw vector r_1 to m, parallel to M_1M_2. Since the direction of relative movement is from r to m, and r is to be found, the reciprocal of rm, or mr, is drawn from m until it intersects the 18-knot speed circle. Thus, rm is the required direction M_1M_2.
4. Complete the speed triangle by drawing vector er_1 from the center of the diagram to r_1.
5. Draw vector er_2 from the center to the intersection of the r_1m vector with the 12-knot circle.
6. Draw vector er_3 in the direction 295°.
7. Draw vector er_4 in the direction 350°.

Check your plot against figure 16-11. Our answers are:

1. DRM 058°.
2. Course 262°.
3. Course 276°.
4. Speed 8.8 knots.
5. Speed 7.9 knots.

This problem is identical with that of problem 2, except that the ship's positions are interchanged. The plot appears the same, except that the relative movement line is in the reverse direction, as described in the explanation of relative movement. It appears on the opposite side of the center, and the labels r and m are interchanged. It should be apparent that either ship may be used as the reference ship and the other considered to be maneuvering with respect to it. The expression MANEUVERING SHIP, when used in connection with maneuvering board problems, may apply to any ship whose movement RELATIVE TO YOUR SHIP is desired, regardless of which ship is actually changing its position in the formation.

PROBLEM 4

Determining the direction of relative movement without plotting M_1-M_2. See figure 16-12.

SITUATION—Your radar operator detects an unidentified contact bearing 310°, 20,000 yards. The DRT operator determined the contact to be on course 190°, speed 16 knots. Your ship is capable of making 18 knots.

ORDER RECEIVED—Intercept the unidentified ship.

REQUIRED—Your course for speed 18 knots.

SOLUTION—Use a scale of 2:1 for speed and distance.

1. Draw vector e-m for 16 knots in the direction 190°.
2. Since you are to intercept the other ship, its relative movement must be direction of your bearing from it. That is, M_2 is

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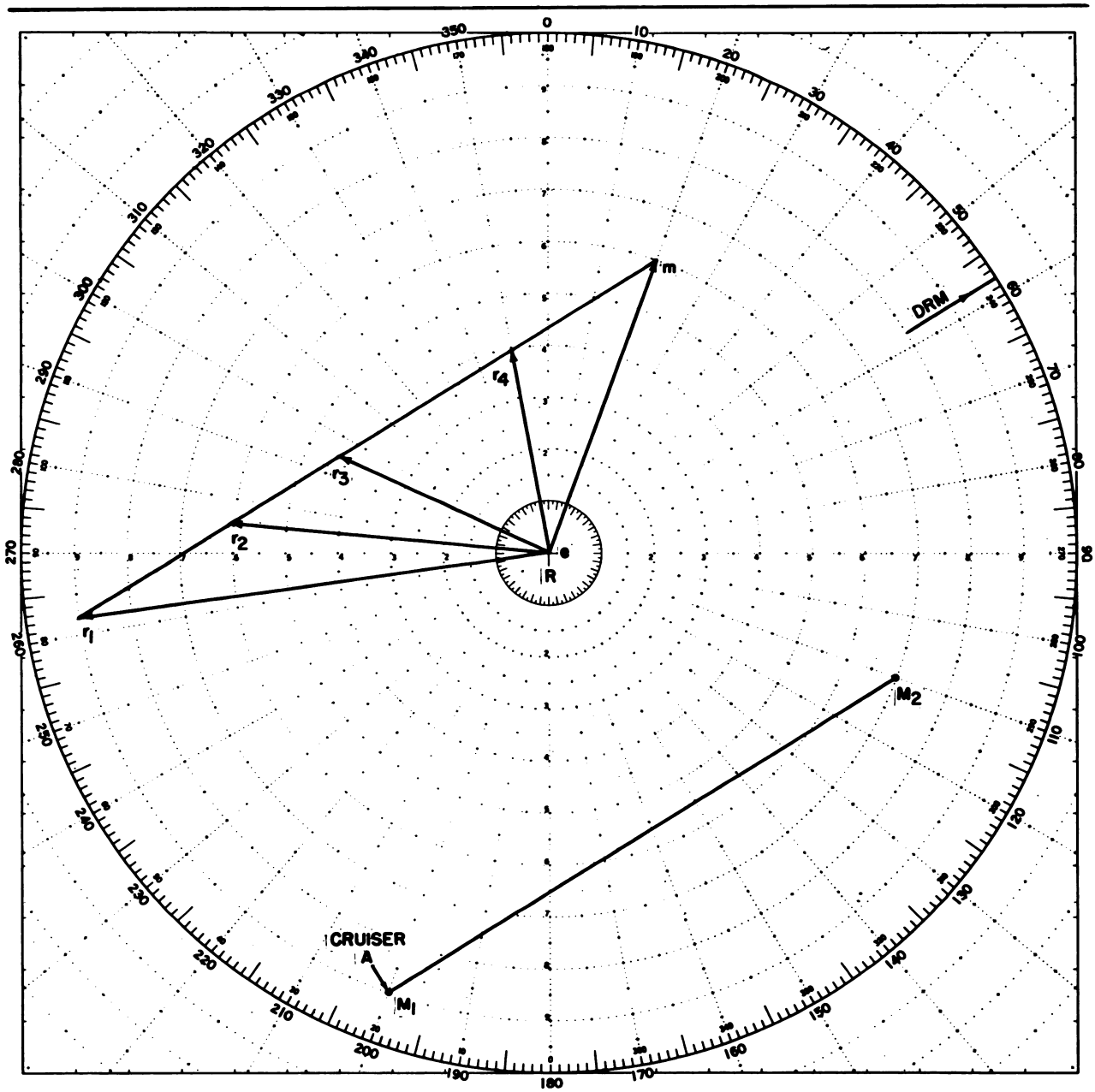

Figure 16-11.—Determining the required course or speed of the reference ship.

at R at the center of the diagram, and M_1 is at 20,000 yards in the direction 310°. Hence the DRM from M_1-M_2 is the reciprocal, 130°.

3. Transfer the DRM line to m, laying off the reciprocal toward r, which is at the intersection of the r-m line with the 18-knot speed circle.

ANSWER—Course 260°

Suppose the OOD wanted to know the time of interception. The two quantities to use the nomogram are already plotted. First, you know the MRM (20,000 yards). The other quantity SRM (19.5 knots) can be obtained by measuring r to m.

ANSWER—31 minutes.

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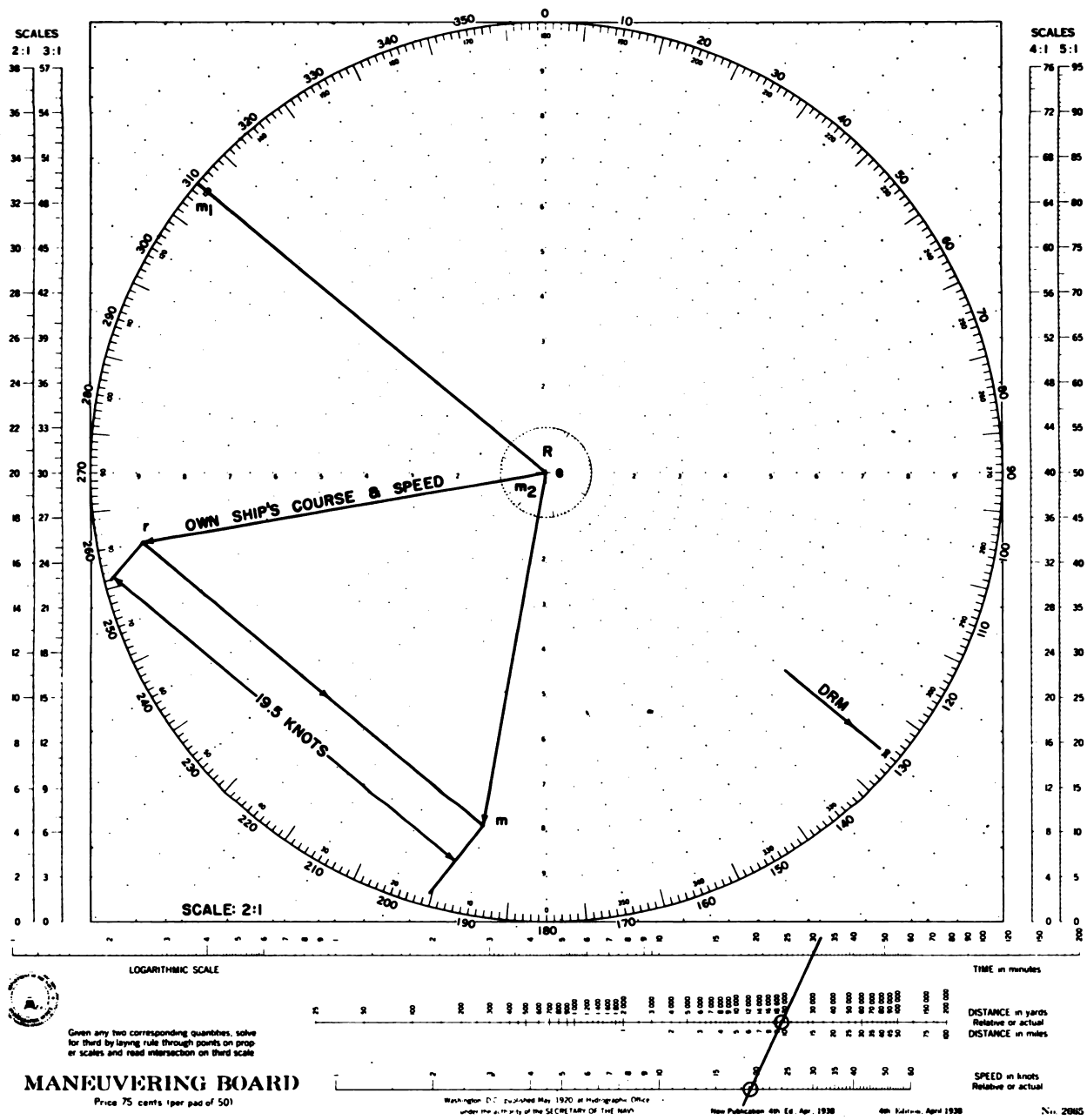

Figure 16-12.—Determining the direction of relative movement without plotting M_1-M_2.

PROBLEM 5

Determining time required to reach new station. See figure 16-13.

SITUATION—The formation is on course 155°, speed 18 knots. The flagship bears 011°, distant 10 miles.

ORDER RECEIVED—Take station bearing 040° from the flagship, distant 5 miles, speed 28 knots.

REQUIRED—

1. Your course to new station.
2. Time required for maneuver.

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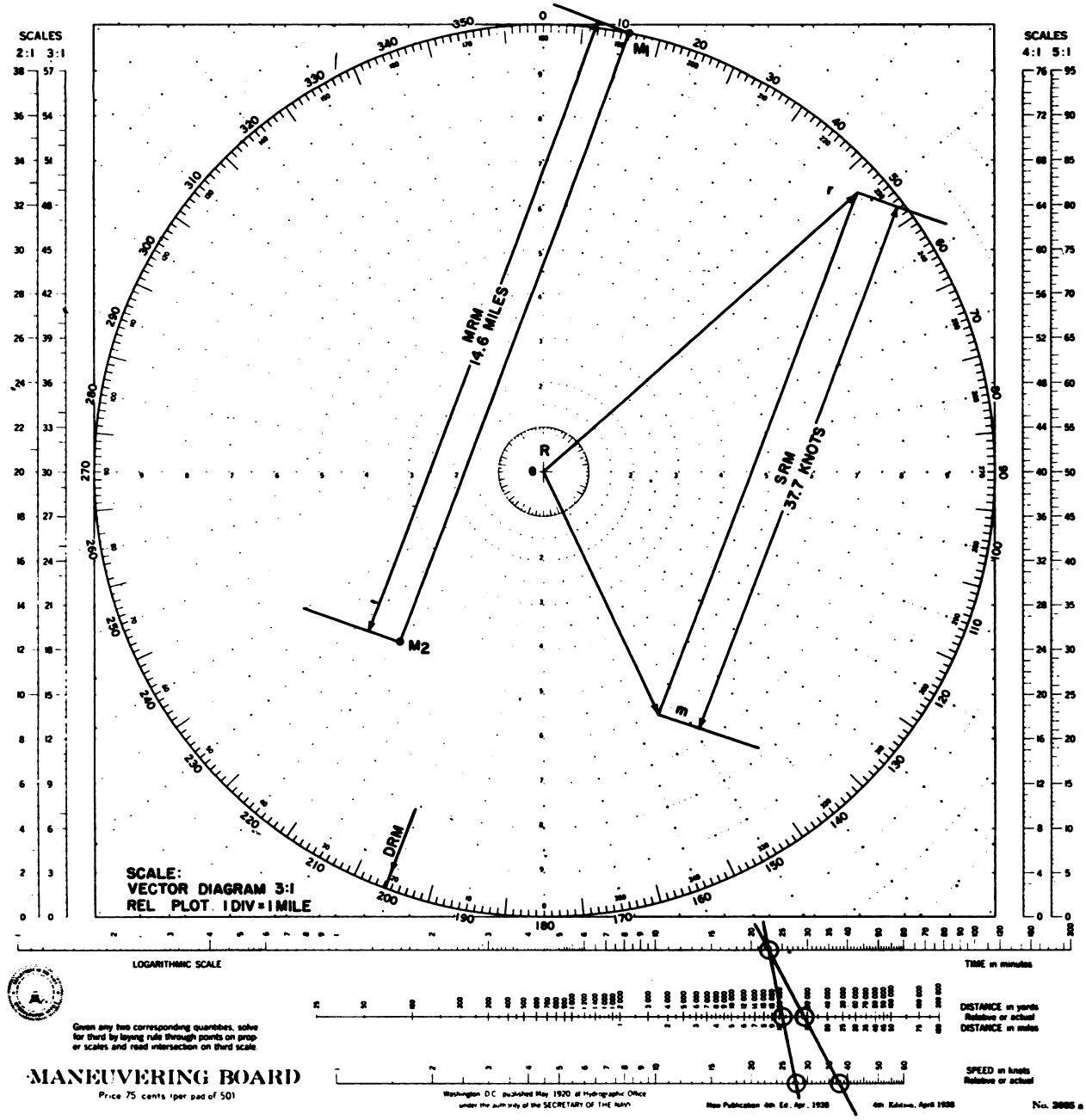

Figure 16-13.—Determining time required to reach new station.

3. Actual distance steamed while changing station.

SOLUTION—Use scales 3:1 in knots and 1:1 in miles.

1. Draw vector e-m for the flagship's course, 155° and speed 18 knots.
2. Locate M_1 and M_2 and draw the DRM line.
3. Transfer the DRM line from M_1-M_2 to m, laying off the reciprocal toward r. The intersection of this line with the 28-knot speed circle establishes point r.
4. Measure the length of M_1-M_2, the MRM, using the distance scale. This is 14.6 miles.

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5. Measure the length r-m, the SRM, using the speed scale. This is 37.7 knots.
6. On the nomogram locate 14.6 miles on the distance scale and 37.7 knots on the speed scale. Connect these points and extend the line until it intersects the time scale at 23. The time is 23 minutes.
7. If preferred, the time can be determined by means of the logarithmic scale (top line on nomogram). Set the right leg of the dividers on 60 and the left leg on the speed, 37.7 knots. Keeping the same spread of the dividers, move the left leg to the distance 14.6 miles. Read off the time, 23 minutes, at the right leg.
8. To determine the actual distance steamed, locate the actual speed, 28 knots, on the speed scale, and connect this point with 23 minutes, previously found, on the time scale. The intersection of this line and the distance scale indicates the actual distance: 10.8 miles.
9. If preferred, the actual distance can be determined by means of the nomogram's logarithmic scale. Set the right leg of the dividers at 60 and the left leg on the actual speed, 28 knots. Without changing the spread of the dividers, move the right leg to 23 minutes. Read the distance, 10.8 miles, at the left leg. (This solution is not shown in fig. 16-13.)

ANSWERS:
1. Course 048°.
2. Time 23 minutes.
3. Distance 10.8 miles.

MANEUVERING BOARD TECHNIQUE

The following hints on maneuvering board problems are derived from studies of the mistakes made by midshipmen at the U. S. Naval Academy.

1. Be sure to read the problem carefully, be certain you understand it before you proceed with the solution. Check all numbers carefully.
2. Avoid using reciprocals. When a bearing is given, be sure you understand to which ship the bearing applies, and from which ship it is taken.
3. Be particularly careful of the scale of the nomogram at the bottom of the form.
4. Measure carefully. It is easy to pick off the wrong circle, or make an error of 10° in direction. Read the plotted answers carefully.
5. Plot only TRUE bearings. If a relative bearing or compass direction is given, convert it to a true direction before plotting.
6. Label all points, and put arrowheads on lines as soon as they are drawn.
7. Remember that relative speed is from r to m. This can be remembered by associating the letters r and m with relative movement. The arrowhead never points in the opposite direction.
8. Actual speed vectors always originate at the center of the diagram.
9. Remember that vectors indicate direction of motion as well as speed. Thus, motion along the relative movement line is associated with relative and not ACTUAL speed. Relative speed is determined when relative distance and time are known. To obtain actual speed, actual distance and time must be known.
10. Remember that the maneuvering board moves with the reference ship; therefore, the reference ship is always at the center of the diagram.
11. Do not attach undue significance to the center of the maneuvering board. This point is used both as the origin of actual speed vectors and the position of the reference ship merely for the sake of convenience.
12. Work a problem one step at a time. An entire problem may seem complicated, but each step is simple, and often suggests the next step. Remember that all problems are based on a few simple principles.
13. The same scale must be used for all speeds, and all distances must be drawn to a common scale.

It is a good idea to refer back to these suggestions periodically, for practically all mistakes result from the violation of one or more of them, or from poor arithmetic.

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QUIZ

1. Is there any relative motion of either of two ships proceeding on the same course and at the same speed?
2. The relative movement method consists of what two distinct but related parts?
3. Does the ship "with respect to which relative movement is to be shown" move or remain fixed on the plot?
4. Where is the reference ship located on the relative plot?
5. What two qualities are defined by the RELATIVE MOVEMENT LINE?
6. What is the only situation in which the relative movement line indicates the ship's actual heading?
7. The speed triangle is composed of three vectors. What are they called?
8. The relative plot indicates bearings and distances. What two qualities are indicated by the VECTOR DIAGRAM?
9. Your ship is on course 300°, your speed is 30 knots. At time 0120, your radar operator reports a surface contact on bearing 048°, range 20,000 yards, closing. The other reports are as follows: 0121-051/19,400, 0122-054/18,700, 0123-057/18,200, 0124-061/17,700.
   Find:
   (a) Course of contact.
   (b) Speed of contact.
   (c) Will the contact pass ahead or astern of you?
   (d) At what range?
   (e) At what time will the contact be ahead or astern?
   (f) At that time, what will be the true bearing of the contact from you?
   (g) What will be the range of the contact when it reaches its point of closest approach to you?
   (h) Its true bearing?
   (i) Its relative bearing?
   (j) At what time will the contact be at CPA?
10. Your destroyer is on course 290°, speed 20 knots. At 1000 combat picks up a radar contact bearing 320°, distance 20,000 yards. At 1003, the contact bears 317.5, distance 18,000 yards. At 1006, the contact bears 315°, distance 16,000 yards, and at 1009, the contact bears 311.5°, distance 14,200.
    Find:
    (a) Course of contact.
    (b) Speed of contact.
    (c) The relative bearing of contact at time 1006.
    (d) Will the contact pass ahead or astern of you?
    (e) What is bearing of CPA?
    (f) What is time of CPA?
    (g) What is range at CPA?
11. Your DD is on station 12,000 yards from the guide on bearing 265°. Your entire formation is on course 320°, making 18 knots. Your DD is ordered to a new station 19,000 yards from the guide on bearing 130°. You are to start the maneuver at 0500, and use a course of 070° en route.
    Find:
    (a) DRM.
    (b) SRM.
    (c) MRM.
    (d) Your speed.
    (e) Time on station.
    (f) Will your DD pass ahead or astern of the guide?
    (g) At what range?
    (h) On what true bearing from the guide?
    (i) At what time will your DD reach that point?
    (j) What will be the true bearing of the guide from your DD?
    (k) What will be the range and bearing at CPA?
    (l) At what time will your DD reach CPA?
    (m) What will be the target angle of the guide at CPA?
12. Your ship is on course 120°, making 24 knots. A contact 20,000 yards from your ship on bearing 170° is ordered to a new position 14,000 yards from your ship on bearing 160° (R). The contact is to complete the maneuver in 40 minutes.
    Find:
    (a) DRM.
    (b) MRM.
    (c) SRM.
    (d) Contact's course and speed.
    (e) Will contact pass ahead or astern of your ship?
    (f) Bearing of contact (true) when broad on your starboard beam.
    (g) Range.
    (h) Time to reach point broad on starboard beam.
    (i) What will be the target angle at that time?

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CHAPTER 17

DEAD RECKONING EQUIPMENT

WHAT IT IS

Dead reckoning equipment, better known as the dead reckoning tracer (DRT), is an important tool for CIC. Properly used, it can maintain a continuous up-to-the-minute geographic plot of your own ship and of all surface contacts within radar range. A knowledge of its design, and proficiency in its use are essential to becoming a Radarman 3.

The principle of the system is based on the form of navigation known as dead reckoning. Dead reckoning is the simplest and probably the oldest form of navigation. It considers only course and speed through the water and ignores set and drift. Nevertheless, a DR track is of great value as a basis from which to establish a true position and is particularly useful in planning and executing tactical maneuvers.

HOW THE DRT WORKS

Since only course and speed are necessary to calculate a dead reckoned position, it seemed reasonable that a device could be built that would do the job automatically. The Arma Corporation of Brooklyn, N. Y., has produced just such a device, known as the dead reckoning tracer. The two known inputs of course and speed are fed to an intermediate analyzer and then to the DRT, where they cause a movable source of light to trace the ship's track continuously. (See fig. 17-1.)

The dead reckoning system consists of (1) dead reckoning analyzer (DRA), view B of figure 17-1, (2) dead reckoning indicator (DRI), figure 17-2, and (3) dead reckoning tracer (DRT), view A of figure 17-1. Notice in view A of figure 17-1 that the DRI is included within the tracking mechanism compartment of the DRT.

DEAD RECKONING ANALYZER

The DRA, located on a bulkhead in the chart house, receives the ship's distance input from the pit log, and the ship's course input from the master gyro. These two inputs are combined to determine and indicate the total distance on a counter as shown in view B of figure 17-1 and also the overall distances in a north-south and east-west direction traveled by the ship from any given starting point. The east miles counter, north miles counter, total miles counter, and course dial are visible through a window in the hinged cover.

The north and east components resolved in the analyzer are transmitted to the DRI and DRT. From an initial setting of latitude and longitude on the DRI dials as shown in figure 17-2, the DRI utilizes the inputs from the analyzer to actuate motors which generate continuously the ship's position and indicate that position on the dials. The inputs from the DRA also drive the mechanisms which drive the pencil drive carrier to record a graphical plot of the ship's travel. A clock mechanism electrically connected to the pencil carrier to the records elapsed time on the graphical plot on the auxiliary plotting table.

The Gyrocompass

A few of the things you learned about the compass in the Seaman course might be briefly reviewed here. You learned that the magnetic compass points to the magnetic rather than to the true North Pole, and that the magnetic pole is located some distance from the true North Pole. You know how the Navy standard compass is made, and how its needle is deflected by magnetic materials in the ship itself, and by magnetic materials brought near the compass.

The fact that the true and the magnetic North Poles are not located at the same spot causes a magnetic compass needle to point more or less away from true north.

The amount the needle is offset is called VARIATION, because it varies at different points on the earth's surface.

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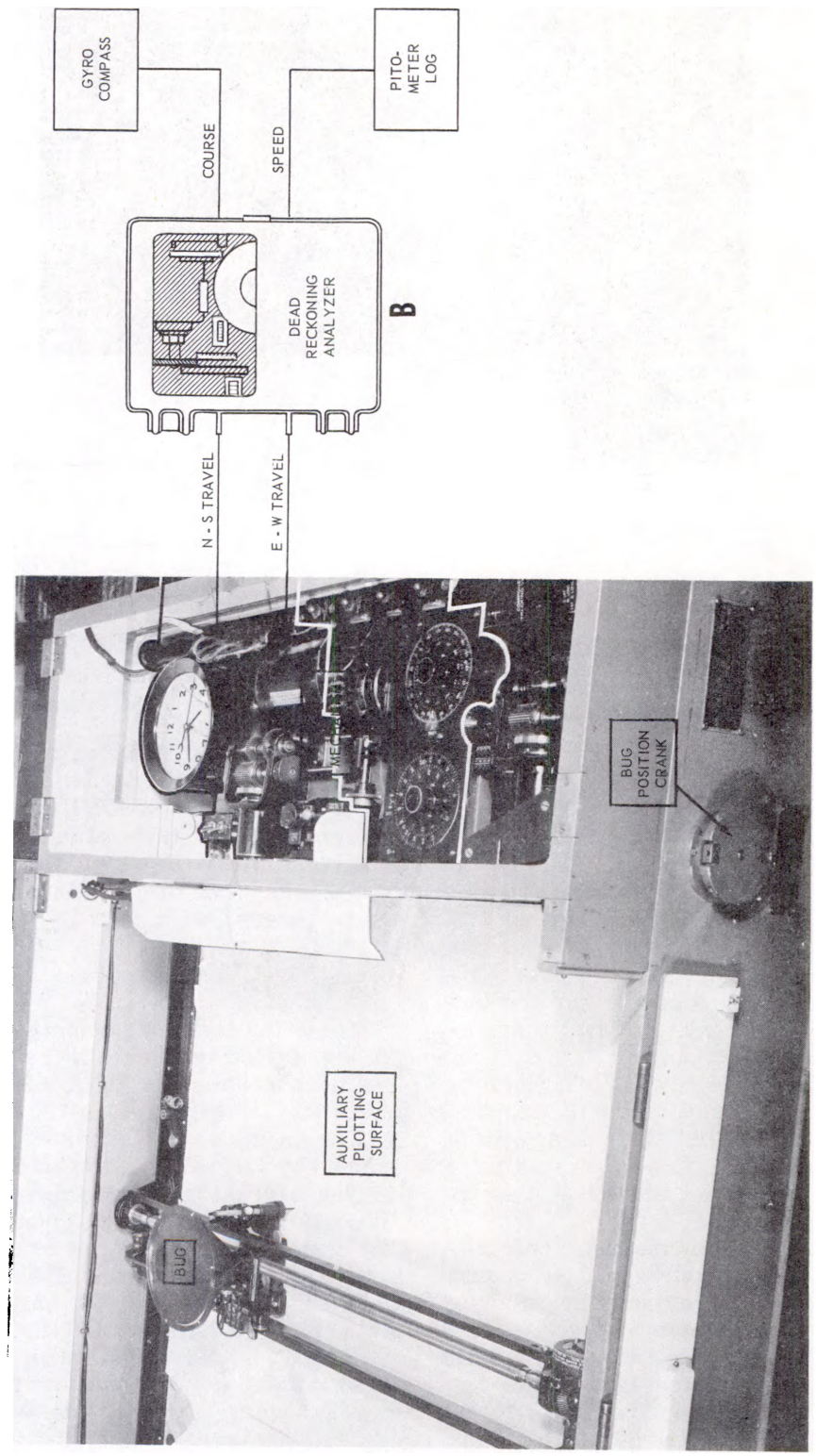

Figure 17-1.—Dead reckoning tracer system.

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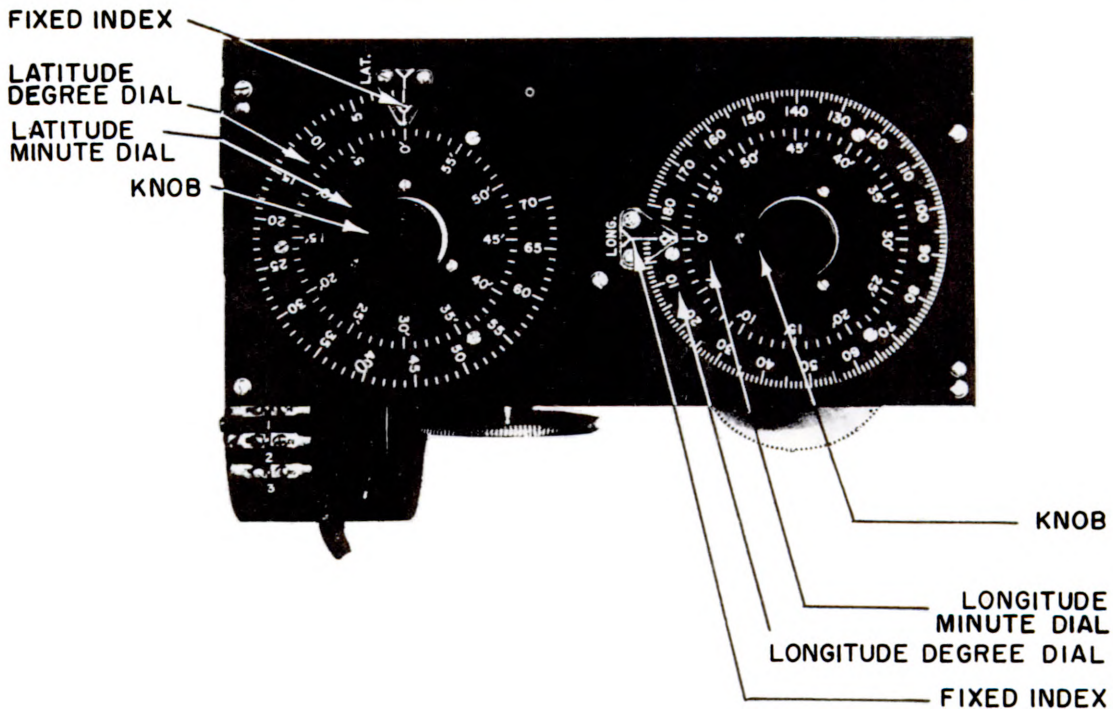

Figure 17-2.—Dead reckoning indicator.

The amount a magnetic compass needle is deflected by magnetic material in the ship around it is called the DEVIATION.

The gyrocompass, as you know, is unaffected by either variation or deviation. Thus, when the gyrocompass is in proper running order it points constantly to the true, rather than the magnetic, North Pole. This in turn sends correct information to the DRA where it is combined with information from the pit log and broken down into components of travel in north-south and east-west directions.

Considering the gyro's advantages, you may wonder why the Navy doesn't heave all the magnetic compasses over the side. Despite the excellence of the gyromechanism, it is the magnetic compass, and not the gyro, that is STANDARD aboard ship.

The reason is this: The magnetic compass operates through the attraction exerted by that great natural magnet, the earth. The earth is absolutely certain to continue to function as a magnet; therefore the magnetic compass will never go out of commission because of any failure of its source of power.

The gyrocompass, on the other hand, is powered by electricity. Cut off the supply, and the gyro is useless. Being a complicated and delicate instrument, it is also subject to mechanical failure. Since the DRT gets its input from the gyrocompass, this naturally will make the DRT inoperative. However, there still is a way that you can use the DRT successfully and it will be covered later.

Pitometer Log

The pitometer log, commonly known as the pit log, is located beneath the hull of the ship and measures the rate of flow of the water passing by it.

The pit log operates by sensing the pressure exerted by the water as the ship moves forward. To sense pressure, a rod meter (known as the SWORD) is lowered about 3 feet below the keel. The rod meter contains two tubes, one having a small hole forward called the DYNAMIC ORIFICE, and the other two small holes, one on either side, called the STATIC ORIFICES.

When the ship stands still, water pressure is equalized in all three orifices. When she moves ahead, however, the water exerts increased pressure against the dynamic orifice, while the pressure at the static orifices remains

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the same. The increased pressure at the dynamic orifice is translated by an electrohydraulic mechanism into readings in knots (accurate to one-tenth of a knot). These readings are transmitted to the DRA and to repeater dials like the one shown in figure 17-3.

All CIC's have at least one of these repeaters mounted in such a manner that the DRT operator, surface plotter, and anyone else concerned can tell at a glance what speed the ship is moving through the water.

In shallow or foul water, the sword must be raised, since the slightest scraping can damage the delicate tubes or bend the sword. Also, fouling of the orifices by seaweed and floating debris can affect the accuracy of the log.

In case the sword is housed (raised), it is possible to insert synthetic speed information into the DRT. This is done with a dummy log controlled from the engineroom. A desired speed is cranked into the device, which then replaces the actual measured speed input, not only to the DRT, but also to all speed-indicating devices throughout the ship. Thus, the purpose of the dummy log is to provide a more accurate speed over the ground where a ship is moving slowly through a known current, or to replace the pit log information when that device cannot

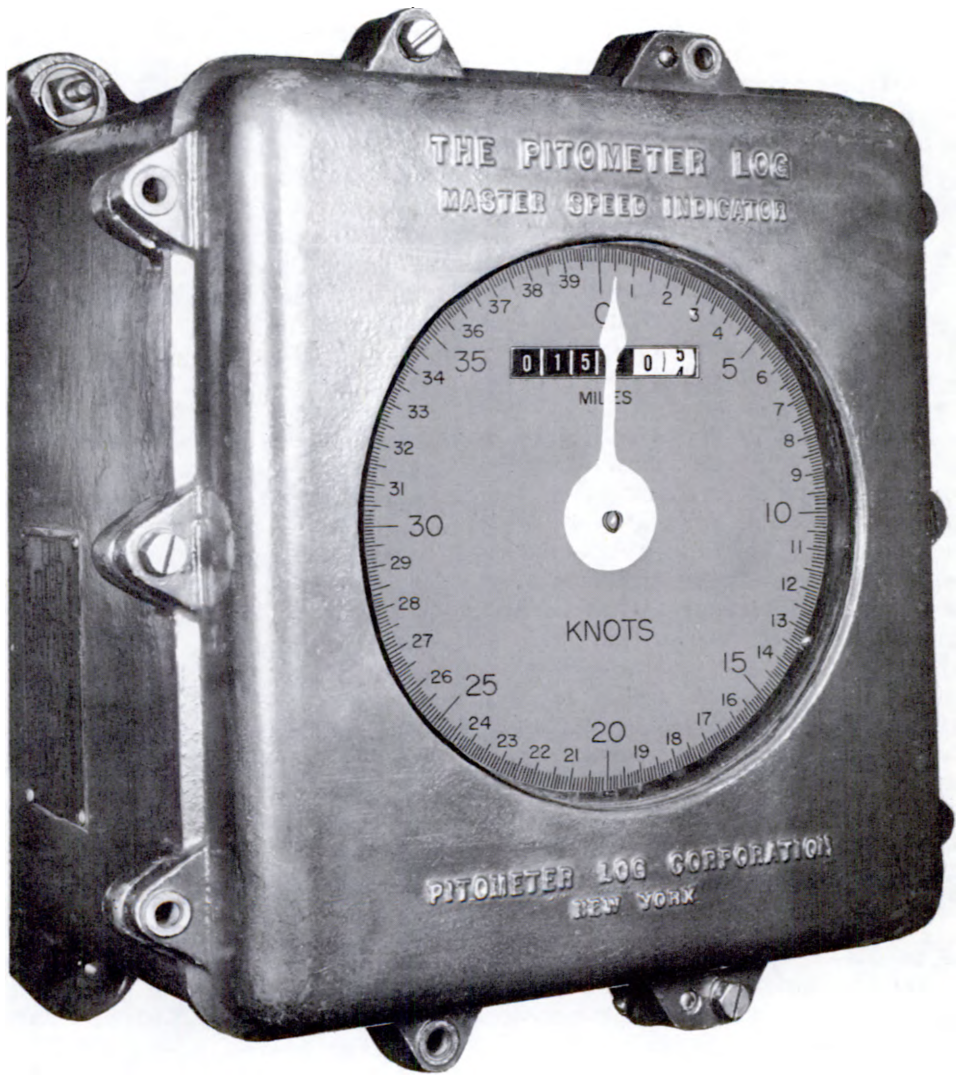

Figure 17-3.—Pitometer log indicator.

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be used. It can also be used to create synthetic problems when the ship is anchored or docked.

The reason for this explanation is to let you know the pit log can develop troubles. Failure of the pit log to operate properly will feed false information into the DRT, causing tracking errors. This in turn will cause errors in the solutions of course and speed problems on the DRT. What you can do about this type of casualty will be discussed later in this chapter.

DRT DRIVE SYSTEM

The components of travel in two perpendicular directions are applied to a pencil carriage and lamp housing (range-bearing projector), popularly known as the "bug" (see figs. 17-1 and 17-6), by means of two threaded drive rods. This drive system reproduces the track of the ship. The initial inputs are electrical; they first pass through a switching arrangement and are then applied to two synchro motors, one for each component of travel. The output of each motor passes through a gear chain and is applied to one of the threaded drive rods or lead screws. The "bug" is clamped to this rod and thus moves proportionally to the original electrical signal. In addition to being fed to the synchro motors, the two electrical inputs are also fed to two other motors which position the latitude and longitude dials on the DRI. The latitude and longitude dial assemblies each consist of two concentric dials. The outer latitude and longitude dials are graduated in degrees, and the inner latitude and longitude dials are graduated in minutes. These dials can be set manually at the beginning of a voyage. At any time thereafter, the ship's position can be read directly from them. In practice, these dials are usually reset at least once a day in order to correct the error caused by set and drift. However, if the ship is maneuvering, the dials are liable to show considerable error unless they are reset periodically to the ship's true position as determined by the navigator. While the ship is underway, the navigator determines the ship's true position at least three times a day, at 0800, 1200, and 2000. The CIC supervisor is usually responsible for obtaining this position from the navigator or his assistant and resetting the DRT. A log is maintained at the DRT, and the latitude and longitude readings are taken each hour and recorded. When the resetting is accomplished, the new setting and old setting are both recorded.

OPERATING CONTROLS

There are three types of controls in the DRT, the electrical controls, the mechanical scale setting controls, and the "bug" positioning controls.

Electrical Controls

The electrical controls shown in figure 17-4 are: (1) ON-OFF switches for each of the two component "bug" drive motors and the latitude and longitude motors; (2) a four-position selector switch for the different combinations of north and south latitude and east and west longitude; (3) a selector switch which determines which side of the DRT plotting table is the north side; (4) a switch to turn on the "bug" light which projects a compass rose on the upper glass plotting surface; and (5) a switch to operate the solenoid which holds the tracing pencil in the "bug" down onto the lower plotting surface. These switches are all located in the narrow compartment at the right side of the DRT, which also houses all tracking mechanism, a clock, and DRI. One other electrical control is a rheostat with an OFF position that controls the intensity of the background illumination between the two plotting surfaces and in the mechanism compartment. This rheostat (not shown in the illustration) is located on the partition separating the plotting surface and control panel. The knob is at the top front corner of this partition on the "bug" side. The rheostat winding itself is in the motor side.

CAUTION: In order to feed power to the lamp and solenoid on the "bug," which must be free to travel in any direction, a "third-rail" system is employed. Two sets of three copper contact strips are exposed within the pencil carriage compartment from which it is possible to receive an electric shock. One set runs along one side, the other perpendicularly across the pencil carriage compartment.

Mechanical Controls

The mechanical scale-setting controls are located in the tracer mechanism compartment. There are two identical pairs of these controls, one for each component, and both must be set identically. One of these is shown in figure 17-5. The scales to which the "bug" may be made to track are 200 YARDS PER INCH and variable from 500 yards per inch to 16 miles per inch. At the bottom of figure 17-5 is a

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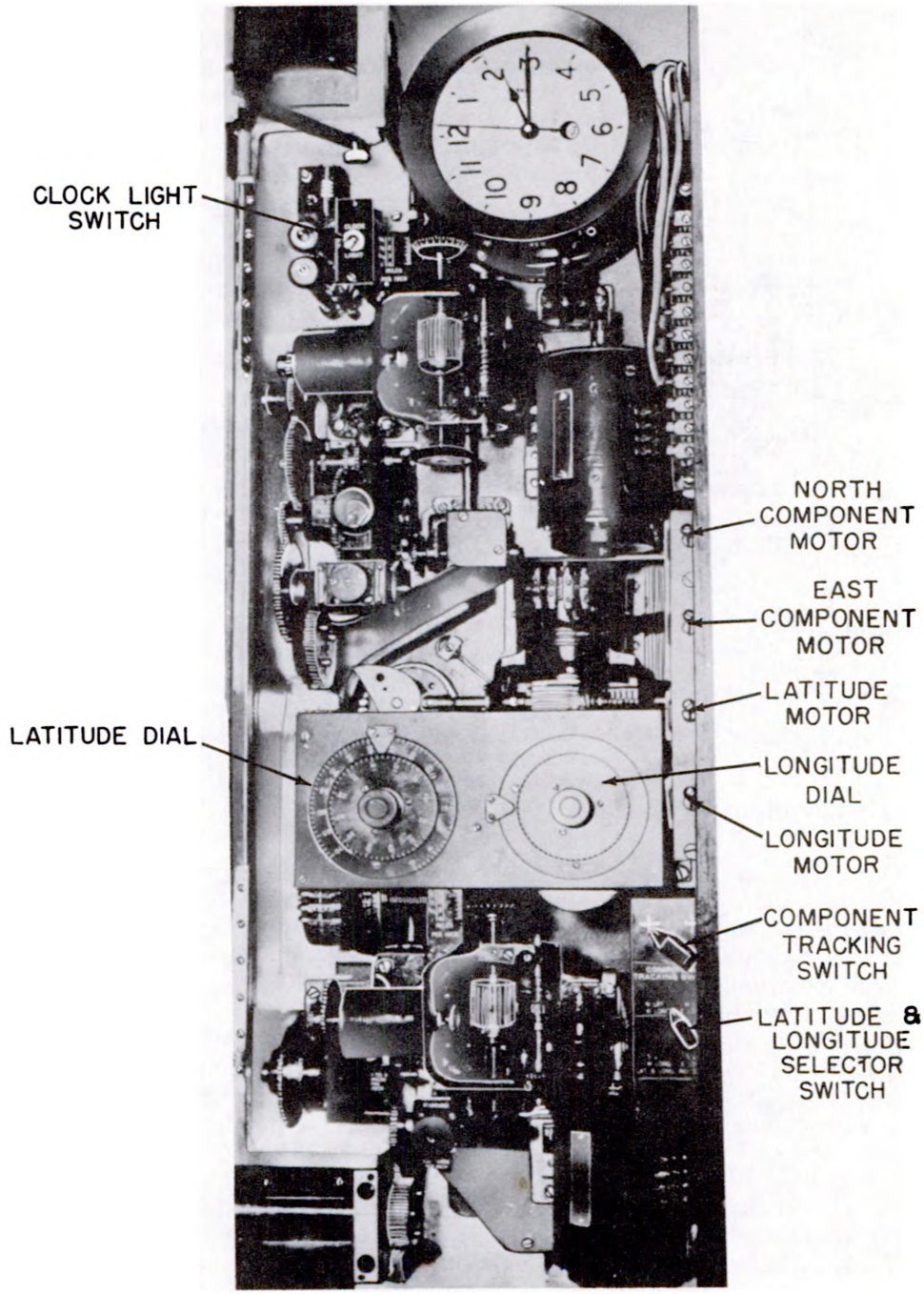

Figure 17-4.—DRT tracer mechanism.

two-position gear shift with a bright yellow knob. Its two positions are STANDARD and "200 YARDS PER INCH." The purpose of having a 200-yard-per-inch scale is to facilitate the accurate plotting and ship handling required in an emergency such as man overboard.

Regardless of what scale was previously being used, the DRT can be quickly switched to the 200-yard scale by shifting the two yellow knobs. The knobs must be raised, rotated 180°, and lowered into position. To select any scale other than 200 yards per inch, the yellow knob

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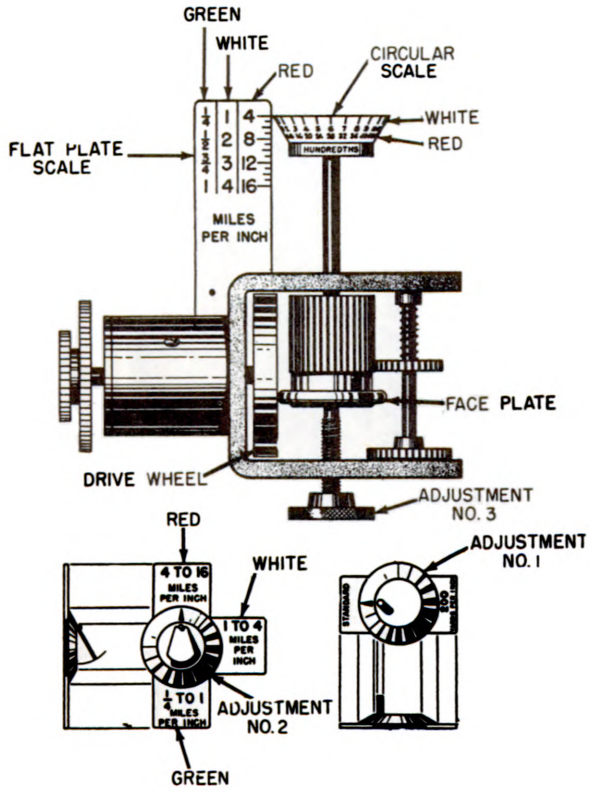

Figure 17-5.—DRT scale adjustment mechanism.

must be in the STANDARD position. The range from 500 yards to 16 miles is broken down into 3 steps: 1/4 to 1 mile, 1 to 4 miles, and 4 to 16 miles. A control knob selects one of the three steps. The three positions are color-coded—green, white, and red. In figure 17-5, this control can be seen immediately above the STANDARD/200 YARD-knob, marked ADJUSTMENT NO. 2. It is shown set on the 4 to 16 mile range. This control is also a gear shift and must be raised, rotated, and then lowered into a locked position. The last step in setting up any given scale is the adjusting of a micrometer type of control which positions the drive wheel across the faceplate of a variable-radius friction-drive mechanism. This control occupies the upper half of figure 17-5, marked ADJUSTMENT NO. 3. The setting is read on two scales appearing at the top of the illustration. In between may be seen the movable drive wheel and, perpendicular to it, the faceplate which it drives.

To set the micrometer adjustment, first determine in which of the three colored scales of the flat-plate scale the desired chart scale lies. This flat-plate scale is labeled with three sets of numbers colored green, white, and red, corresponding to the three positions of the gear shift. On the green scale, each of the 16 divisions represents 125 yards. On the white scale, each division represents 1/4 mile, and on the red, each division represents 1 mile.

The control is set by rotating the micrometer or circular scale. One full revolution lowers it one mark on the flat-plate scale. The circumference of the micrometer (circular) scale is marked off into 25 major divisions, each of which is subdivided in half. The 25 divisions are numbered in white from 0 to 25 and in red, by fours, from 0 to 100. The fine adjustment is made by setting the proper unit (or fractional point between units) of the micrometer scale exactly at the edge of the flat-plate scale. When using the green portion of the flat-plate scale, use the white markings on the micrometer scale. Each unit represents 5 yards. When using the white portion of the flat-plate scale from 1 to 4 miles, the white markings of the micrometer scales are again used and represent hundredths of a mile or 20 yards. Finally, with the red portion of the flat-plate scale, use the red markings of the micrometer scale and again read them as hundredths of a mile.

"Bug" Controls

The remaining controls of the DRT are those that allow the operator to reposition the "bug" manually. There are two methods of doing this. The first is to disengage the clamps that travel on the threaded drive rods. The clamps are held against the drive rods by a spring. By depressing a lever, thus overcoming the spring pressure, the carriage is freed and may be rolled smoothly from one end of its travel to the other. The lever to move the "bug" in a sideways direction (labeled B in fig. 17-6) is just inside and at the bottom of the front panel. It must be pressed sideways against a rigid member to disengage. The entire cross-feed mechanism can then be rolled in either direction. The clamp on the cross-feed drive rod is on the "bug" itself. It is a small lever (see front view, fig. 17-6) which must be pressed down, to move the "bug" in an up and down position (north-south, normally). As shown in the illustration, figure 17-6, it is low and on the near right side of the "bug" mechanism.

This method of moving the "bug" does not permit fine positioning, as the clamps must

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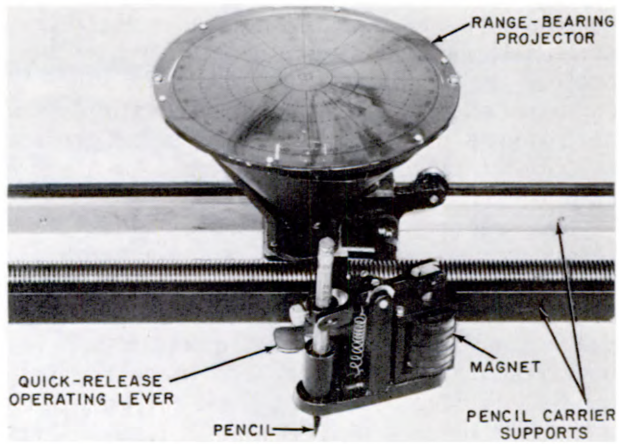
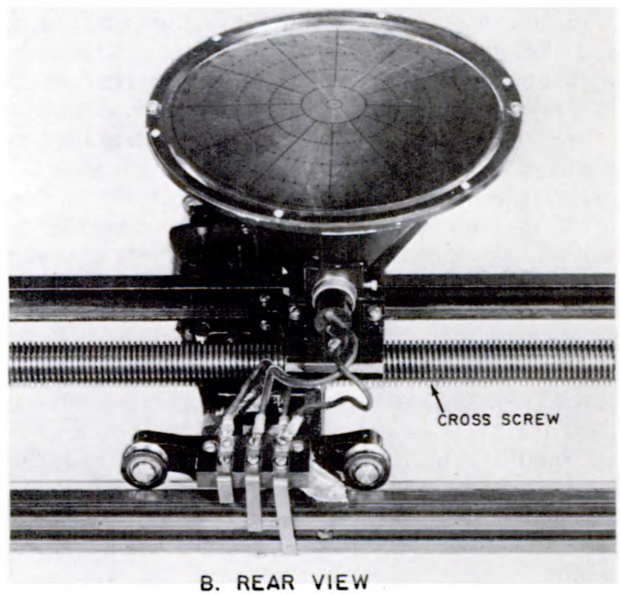
engage the threads of the drive rods. It cannot be left with the "land" of the threads in the clamp against the "land" of the drive rod. Therefore, a method of positioning in which the drive rods themselves are turned is necessary. This is accomplished by the addition of two handcranks on the front of the DRT. Normally held out by spring pressure, these handcranks when pressed in are mechanically geared to each of the drive rods. However, there is no simple means of mechanically disconnecting the drive rods from their respective motors. Therefore, in order to avoid bucking the motors when using the handcranks, two microswitches are installed, one for each handcrank, in such a manner that when the crank is depressed, the electrical circuit to the corresponding motor is broken. When the crank is then turned, the motor spins freely with it in either direction. This method of moving the "bug" is slow and used only for fine adjustments such as positioning the "bug" on a chart for navigational purposes.



A. FRONT VIEW



B. REAR VIEW

Figure 17-6.—DRT pencil carriage assembly.

THE GEOGRAPHIC PLOT

As described thus far, the DRT is capable of doing one thing—producing a geographic record of the ship's path. It may do this automatically by means of the pencil carried across a paper fastened to the table surface immediately below the "bug," or an operator may periodically mark the center of the compass rose projection on a tracing paper fastened on top of the upper glass plotting surface. The former method is rarely, if ever, used, due to the inaccessibility of the plot for making additional or explanatory notations. However, it has a distinct advantage in not requiring the plotter's attention once every minute. In certain cases, then, it may be desirable to use both plotting methods simultaneously and later superimpose the one plot on top of the other.

It was stated earlier that the DRT was developed as a navigational tool. Today, in the age of radar, it has found even greater usefulness in the field of combat operations, but its value as a navigational aid still remains. The geographic plot can be made directly on a chart to show the ship's path in and out of a harbor or around islands. When so used, the mechanism of the DRT must be set to the scale of the chart. The scale of a chart is usually expressed as a pure ratio, such as 1/20,000. This means that 1 inch on the chart corresponds to 20,000 inches on the earth. This figure can be converted to yards per inch by dividing by 36, or to miles per inch by dividing by 72,000. In practice, the major navigational function of the DRT is carried out by the latitude and longitude dials which provide up-to-date DR position, regardless of alterations to the scale or the position of the "bug."

The greatest value of the DRT is its use in analyzing the movements of ships and in planning and carrying out maneuvers. As a geographic plotting device, it uses true courses and speeds. Marking the positions of the bug indicates the true positions of own ship. Connecting the plotted positions yields the ship's track. Plotting in the ranges and bearings of contacts using own ship's

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positions as references establishes their true positions. The tracks are established by connecting these positions as with own ship. An experienced DRT operator can maintain plots of as many as half a dozen contacts and provide solutions to maneuvering problems for his own ship in relation to these contacts.

The record which the DRT provides of an action during wartime may be an invaluable aid both in conducting a surface engagement and in the later reconstruction of the situation. In peacetime, it may be equally important in cases of grounding or collision. For these reasons, the DRT tracing becomes a legal record just as the ship's log is a legal record. It must be kept neatly and accurately, and clearly labeled. The complete legend must show a north-south reference line, the name of your ship, the scale used, and the date and name of the plotter. Erasures may not be made on the plot. Information which is erroneous or put down by mistake should be crossed out with a single line. DRT tracings of such nature as mentioned in preceding paragraphs should be stored on board for a period of 6 months unless otherwise directed. When used to record the tracks of ships well clear of land, no chart is used on the DRT. This permits the operator to choose whatever scale setting he finds most convenient. For such purposes, the 2000-yard-per-inch scale is the most popular. The 30-inch-square plotting area of the DRT then becomes a 30-mile-square.

Should a more detailed plot be desired, the scale may be increased to 500 yards per inch. The 200-yard-per-inch scale is usually used for man overboard and gives an area of 3 miles on a side.

If a larger area is required to record, say aircraft operations in an antisubmarine exercise, it may be increased up to 480 miles on a side by reducing the scale to 16 miles per inch. When not using a printed chart, some other distance scale must be employed to enable the operator to measure and plot distances. Most commonly employed is the plastic rule which attaches to the parallel motion protractor (PMP). Figure 17-7 is an illustration of the two plastic rules in common use. One has scales of 2000 yards and 500 yards per inch; the other has scales of 1000 yards and 200 yards per inch. If a scale for which no rule is available is to be used, a scale must be made up by measuring inches and fractions of inches and labeling it accordingly. This may be drawn along the edge of the tracing paper and a pair of dividers used to transfer the distances, or it may be drawn on a strip of paper tape and fastened to a plastic rule for use with the DRT.

PARALLEL MOTION PROTRACTOR

Basically, the PMP is a device which allows a straight edge positioned in any desired direction to be moved anywhere on the plotting surface at all times, maintaining the same direction. One end of the PMP is fastened rigidly to the framework of the DRT. The other end of the two-section, pivoted arm carries a bearing circle and can be moved anywhere over the plotting surface. The plastic rule fits into a holder which is pivoted at the center of the bearing circle. A circular plate bearing four index marks spaced 90° apart, carrying with it the plastic rule, rotates adjacent to the bearing circle and provides the means of measuring exact directions. The bearing circle may be rotated, aligned with the DRT "bug", and locked in position. The plastic rule may be either free

Figure 17-7.—Range rulers.

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to rotate or locked in any desired direction. The two locks which control these functions are located on the bearing circle assembly, the innermost lock being the rule lock, the outer the bearing circle lock. Figure 17-8 illustrates a parallel motion protractor with rule attached.

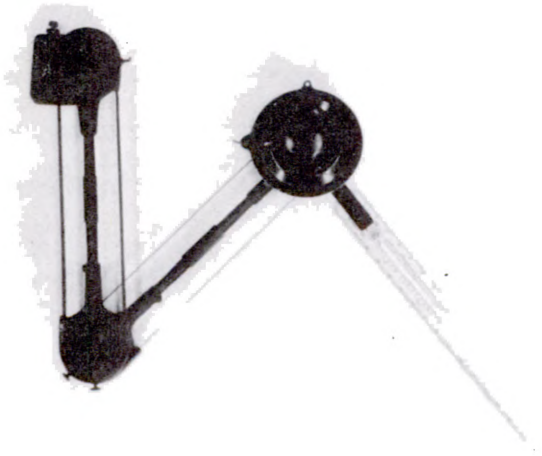

Figure 17-8.—Parallel motion protractor.

ALIGNMENT PROCEDURE

In normal use, the bearing circle is lined up with the DRT "bug," locked, and then not disturbed until there is reason to believe it may have slipped or been unwittingly changed. The alignment procedure consists of turning on the light in the "bug" and turning off the drive motors. The position of the "bug" is marked. It is then moved manually a foot or more in one of the four cardinal directions and marked again. These two marks then may be used to line up the plastic rule. The bearing circle is then locked so that the cardinal headings match the four indices (or crow's feet). The clamp which locks the plastic rule to the bearing circle may be used repeatedly without disturbing the alignment of the bearing circle itself. An alternate method of holding the rule in a desired direction while sliding it across the plot is to hold the bearing circle and the index circle tightly with the thumb and forefinger. This latter method is slightly faster and seems to be preferred. There are slightly different models of the PMP in use, some of which have controls and locks not found on others. However, the two locks described are common to all.

DEVELOPING YOUR OWN SHIP'S TRACK

The moving "bug" indicates the position of your ship at all times. For example, suppose your ship is steaming on a course of 090° at 15 knots. If you place a pencil mark in the center of the "bug" at time 1500 and again 3 minutes later, the "bug" would have traveled 1500 yards in a direction of 090°. To measure the distance traveled take the PMP ruler and lay it in a line from dot to dot in the direction of "bug's" movement. You may then read the distance in yards traveled directly off the scale. Read the ship's course off the PMP bearing indicator. By marking a small dot over the light, the track of your own ship is developed. When you start a track, record the latitude and longitude from the latitude and longitude dials for the purpose of a future reference.

Indicate the time alongside your own ship's track. On the first plot show the hour and the minute in a four-digit number. For succeeding positions on the same track, only two-digit numbers, indicating minutes, are necessary until the next hour. Then record the four digits again to show the hour to which the minutes refer. Occasionally it may be necessary to show the quarter-minute time exponents alongside the track.

Time Exponents

Time exponents are recorded on the plot by placing a small exponent above and to the right of the minute digits. These exponents represent the nearest quarter of a minute. For plotting purposes, when more accuracy is required, each minute is considered to be divided into the following quadrants:

Exponent 1	7 1/2 to 22 1/2 seconds (after the minute)
Exponent 2	22 1/2 to 37 1/2 seconds
Exponent 3	37 1/2 to 52 1/2 seconds
No exponent	52 1/2 to 7 1/2 seconds (represents the even minutes).

Figure 17-9 shows how these exponents appear on the face of a clock used in CIC. The time illustrated is 12^2, spoken as "twelve prime two."

Your CIC may have a direct reading clock, like the one in figure 17-10, mounted next to the DRT. This type of clock automatically shows the correct exponent. They make the noting of time considerably easier.

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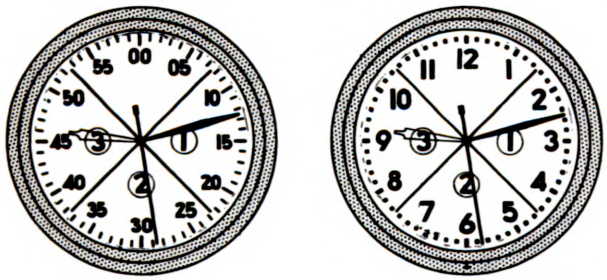

Figure 17-9.—Time exponents as used on CIC clocks.

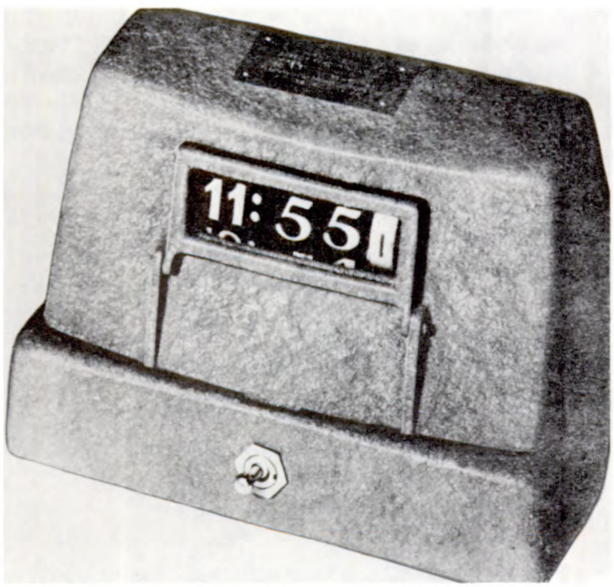

Figure 17-10.—Direct reading clock.

PLOTTING BEARINGS AND RANGES USING THE PMP

Bearings are determined by the use of the bearing indicator on the PMP. For your convenience, several different range rulers are provided for use in plotting ranges. Two of the more common range rulers were illustrated in figure 17-7. As discussed before, they are marked off in range scales that are generally used in DRT tracking, so by using the proper ruler you can plot the range in yards, directly on the DRT.

You'll find it surprising how often the PMP will get in your way as you plot. To eliminate awkward movements of the protractor, two methods of plotting ranges and bearings have been developed: direct and indirect plotting. Use the one most convenient for the contact you're plotting. This will vary, depending on the contact's range and bearing, the position of the "bug," etc.

DIRECT PLOTTING

Figure 17-11 illustrates the direct plotting method. This method can be summarized in the following steps:

1. Plot the position of your own ship at the time the range and bearing were taken.
2. With the range ruler free to rotate, set the bearing indication arrow that points toward the ruler on the desired bearing, then lock the PMP. Be careful not to lock the PMP too tight because when you go to unlock the PMP it may be thrown out of alignment.
3. Place the zero mark on the ruler exactly on your ship's position. The edge of the ruler now extends along the true bearing line from your own ship's position.
4. After hearing the range, repeat it mentally while placing the protractor in position. Now read outward from zero to the contact's reported range (in thousands of yards) and mark the point.
5. Immediately after establishing this point, release the lock on the PMP, leaving it ready for use. Record the same time, at the plot of the contact, that you recorded next to your own ship's position you plotted from. (Not shown in illustration for the sake of clarity.)
6. Move the PMP clear of the plot so that the evaluator will have an unobstructed view and the plot can be "dressed up."

INDIRECT PLOTTING

Figure 17-12 is an example of indirect plotting. Indirect plotting makes use of the reciprocal bearing mark on the PMP. This makes the plotting of targets easy that are awkward to handle by direct plotting. Here are the differences between direct and indirect plotting:

1. Read the desired bearing beside the arrow, which is 180° from the ruler side of the PMP arm.
2. Place the desired range, instead of the zero mark, at the marked position on your own ship's track.
3. Plot the target's position at the zero mark on the ruler.

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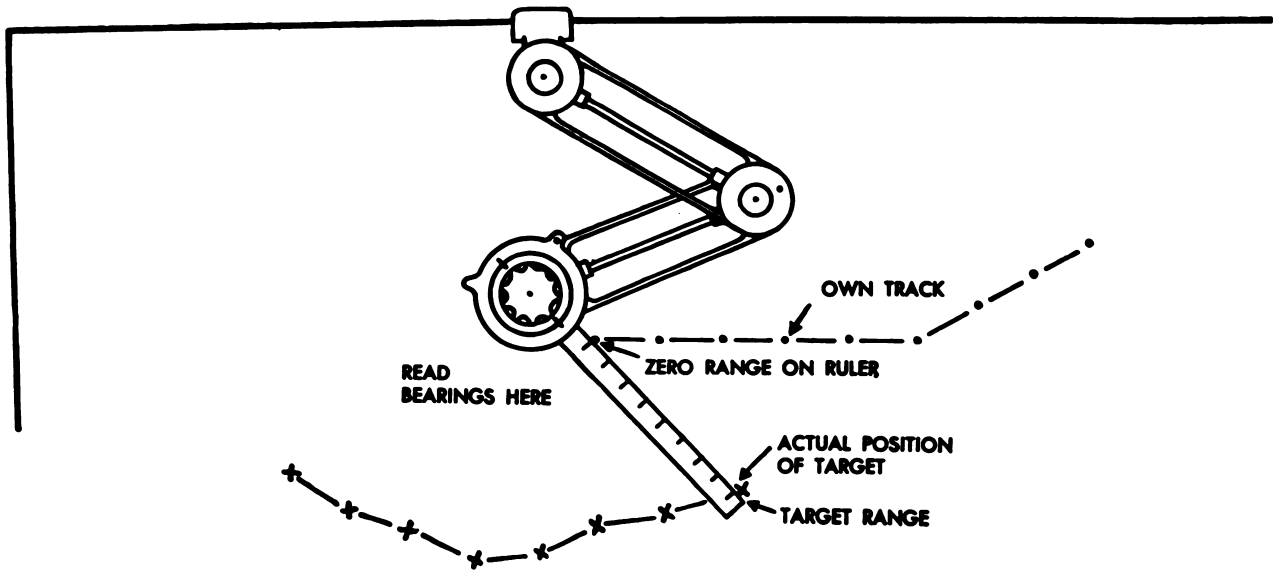

Figure 17-11.—Direct plotting.

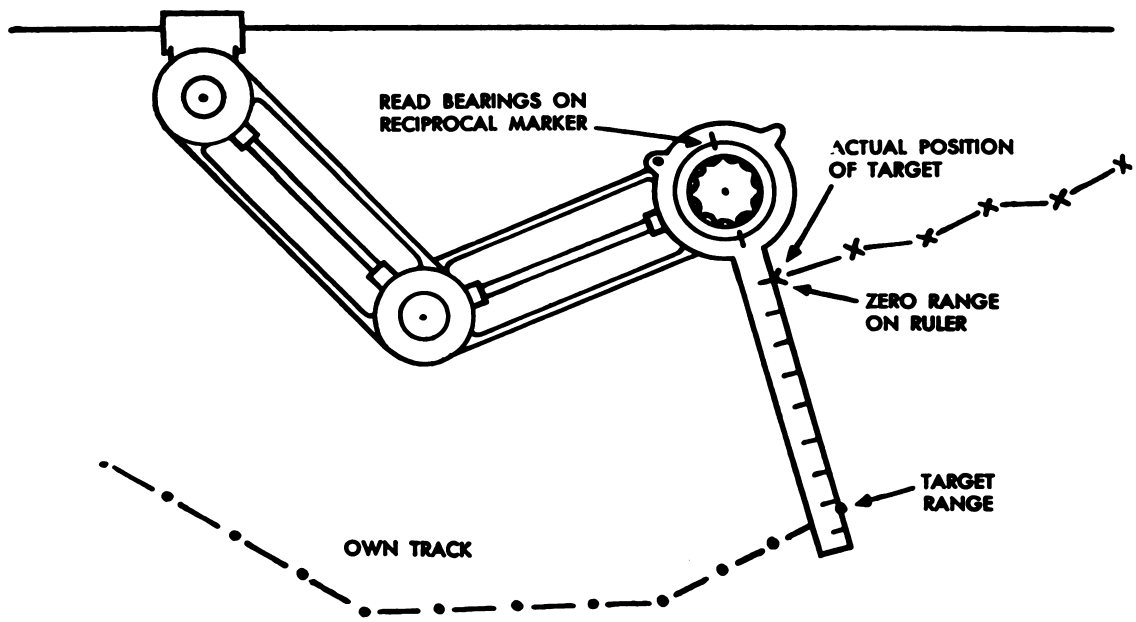

Figure 17-12.—Indirect plotting.

Many times, as the DRT operator, you will be required to keep track of several contacts. If you were tracking five contacts and only plotted each one once a minute, the plots of each contact would be 5 minutes apart. This period of time (5 minutes) between plots is much too great. A lot can happen in 5 minutes. One of the qualifications of the Radarman Third or Second is to maintain a track of at least three contacts a minute on the DRT. This means that the radar operator will be sending ranges and bearings over the phones pretty fast. Often this requires you to remember many numbers at the same time you are figuring each contact's course and speed. As an aid to your memory, most ships have a surface recording board like the one

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illustrated in figure 17-13. This board may be just a section of the surface status board, or it may be a board all by itself. Here is how it works.

RAID	BRG.	RNG.	TIME	CUS.	SP.	CPA.	TIME OF CPA.	REMARKS
A	246	15,400	0701					
A	242	15,150	02	240	14			
A	239	14,800	03			116/500	0726	1M
B	019	22,300	02					
B	020	22,000	03	156	22	178/4500	0747	2DD

Figure 17-13.—Surface recording board.

The person who mans this position, called the surface recorder, is usually an off-seat operator who is on the same sound-powered phone circuit as the radar operator and the plotters. He records each range and bearing as it comes over the circuit from the radar operator and the time of each report.

This record serves to keep the evaluator informed and as a backstop to the plotters. In case the plotters missed the range, bearing, or time of a report, they can refer to the recorder board. As soon as the plotter obtains a course and speed solution, and the point and time of the closest approach of the target, the recorder enters this information on his board.

The recorder may act as a timer for both the radar operator and the plotters, when the STANDBY-MARK method of plotting is used. In this case, he watches the clock and says "STANDBY." This warns the radar operator to have a bearing and range ready and the plotter to stand by to mark the "bug's" position on the DRT. Ten seconds later, on hearing "MARK" from the recorder the plotter marks the "bug" and the operator sends the range and bearing to the plotter. On receipt of the range and bearing, the plotter plots the contacts. This method is used when several surface targets are being tracked at the same time. You also use this method for tracking submarines on the DRT using ranges and bearings from the sonar gear.

The edge lighted board's plotting surface is usually made of plexiglass. The entries are made in grease pencil, and erased with a clean rag when they are no longer needed.

DETERMINING TARGET COURSE

Now that you know where and how you gain information to be plotted on the DRT and how to plot a target's position, let us go into the matter of determining target's course.

Remember how we discussed determining your own ship's course by laying the PMP ruler along the pencil dots that were caused by your marking the "bug?" Well, a target's course is determined in the same manner. Lay the PMP ruler along the target's plots and read the indicator on the PMP. Be sure you select the bearing in which the target is moving. A word of caution: The plots will not always fall in a smooth track as those of own ship's. They will often be erratic. This can be caused by a "green" radar operator giving ranges and bearings that have a couple of hundred yards and a few degrees error. Figure 17-14 illustrates what to do in this case. Lay the PMP ruler along the mean of the plots and read the bearing indicator. If the contact's plots moved from right to left, you'd read the bearing indicated on the left side of the PMP.

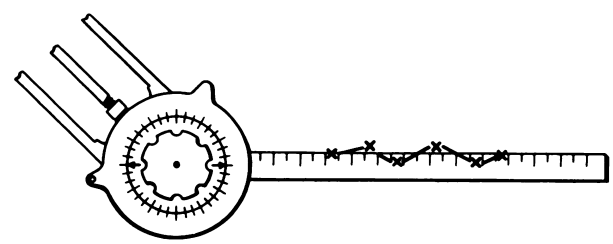

Figure 17-14.—Course determination.

DETERMINING TARGET SPEED

In spite of the fact that many gadgets have been developed to help you determine speeds of targets on the DRT, none of them are as fast, or as satisfactory as what is known to the Radarman as the 3-minute rule. The 3-minute rule is used on the maneuvering board, surface plot or the DRT. The 3-minute rule is also used in air plotting differing only in that the scale is in miles rather than yards.

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Basic Formula for Determining Speed

Speed can be determined by the basic formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

When the distance traveled in yards is divided by the time in minutes, speed expressed in yards per minute is obtained. To convert to nautical miles per hour (knots), multiply by 60 minutes to get yards per hour, then divide by 2000. For example, a target travels 1100 yards in 3 minutes. Applying the basic formula, the speed of the target is found to be 11 knots.

Three-Minute Rule

Using the 3-minute rule, you simply find the number of yards the contact traveled in 3 minutes and point off, or drop two numbers from the right-hand side of this figure. For example, if the target traveled 1700 yards in 3 minutes, its speed is 17 knots.

You can make the same easy rule apply to cases where you have only 2 minutes of target travel, by changing the actual travel in 2 minutes, to a figure for 3 minutes of travel. For example, a contact has traveled 800 yards in 2 minutes. This target would travel 400 yards in the next minute, making 1200 yards in 3 minutes. Therefore, its speed must be 12 knots. By the same kind of mental arithmetic you can stretch the 3-minute rule to cover a minute, or a minute and a half of travel. Thus, if a target covers 800 yards in a minute and a half, it would travel 1600 yards in 3 minutes, and its speed is 16 knots. If it traveled 1100 yards in 1 minute, it would have covered 3300 yards in 3 minutes, and must be making 33 knots.

As stated before, there are many other gadgets developed to simplify the problem of solving target speed. Some of them are: speed-time nomograms, logarithmic nomograms, nautical slide rules, etc. One of these time saving devices in determining a contact's speed is printed on the plastic range ruler attached to the parallel motion protractor. Notice in figure 17-7 that each side of the ruler has speed scales to be used in conjunction with the DRT scale setting. For example, suppose you are tracking a target on the 2000 yards per inch scale. To find the speed of the contact after 1-1/2 minutes of plot, merely lay the speed scale for 1-1/2 minutes along the track and read the scale. Notice also that each range scale has slightly different speed graduations; thus, YOU MUST BE VERY CAREFUL TO USE THE PROPER TIME AND DISTANCE SCALE. At times these speed scales can be very useful, especially when dead reckoning your own ship. However, if you learn the simple 3-minute rule, you will find these gadgets not strictly necessary for any work required on the DRT.

CONTACT DESIGNATION

Surface contacts are designated by the word TRACK following by a letter or letters assigned in sequence, beginning at 0000 local time. They are referred to by the code words SKUNK or FRIENDLY as appropriate. For example, SKUNK A, FRIENDLY B, etc. If there are insufficient letters for designation, two letters such as AA, AB, AC may be used.

When a contact has been designated, it is identified on the plot by placing the letter designator in a large circle (size of a quarter) near the origin of the series of plots it identifies.

If a surface track splits into two or more parts, each part is assigned a secondary numeral after the primary letter designator by the ship that reports the split. Secondary numeral designators are assigned in order, increasing clockwise from true north at the point at which the split occurs, for example, SKUNK A1, SKUNK A2. The primary letter designator and the secondary numeral designator are placed in a circle near the point of the split. If a split contact with secondary designators assigned should split again, letter designator suffixes are assigned in the same order as numeral suffixes, for example SKUNK A1A, SKUNK A1B. If two parts of the contact are on the same line of bearing, the part nearest the ship is assigned the smaller designator number. Later, the parts of a split may be redesignated, for example, SKUNK B2 may be redesignated SKUNK D and SKUNK B1 as SKUNK B.

DATA TO BE RECORDED ON PLOTS

By use of symbols and abbreviations to be explained later, in boxes alongside your track, and the track of the enemy, your plot can give the full story of the situation. If can show a blow-by-blow account of a surface engagement or an antisubmarine attack. The picture it presents depends solely on your ability and skill as a plotter. Let's look at the information a top DRT man records on his plots.

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Figure 17-15 helps illustrate the proper method of recording data.

Alongside own ship's track indicate such information as point of opening fire, point of firing torpedoes, number of torpedoes fired with corresponding arrows, base course and speed, point of dropping depth charges, point where own ship received shell or torpedo hits, or anything that own ship does or that happens to own ship during the track.

Next to the target's track indicate the composition of the contact by number and types, or the best estimate available. Before number and types are established, the best information will generally approximate the number as one, few, or many, and the types will be classified as large or small. The composition of the contact is always boxed. If the information is only in terms of one, few, or many, the box should be made large enough to permit the insertion of a later report of the exact number and type.

The target designation letter should be circled at the beginning of the track. Be sure to use the method of designation as explained previously.

Include amplifying data along the enemy track such as slowing, on fire, or anything that happens to the target. If the source of information is other than radar, such as a lookout report or a sonar report, record this fact on the plot.

The mode of IFF shown by a friendly contact should be placed beside the track at the point where it is reported by the operator. The symbols should be of prominent size and should not be enclosed in a box.

Where appropriate, the following additional data should be included on the plot: reference points such as Point ZULU, Point OSCAR, PIM, or geographic points; wind force and direction; arrow indicating true north placed in such a position that it will not interfere with the plot; latitude and longitude of own ship; and scale of plot. Last, the date is included.

PLOTTING SYMBOLS AND ABBREVIATIONS

On the DRT, just like any other type plot, you try to show as much information as possible. The more complete your DRT plot, the easier it will be for the evaluator to read the plot and make his recommendations to Conn. Table 17-1 is a list of plotting symbols and abbreviations you should use in keeping a plot on the DRT or surface plot.

DRT CASUALTIES

Like any other mechanical and electrical device, the DRT is not infallible. Always be prepared for a casualty. Should this happen, immediately extend your present course line from your last position plot. For example, should your ship be on course 260° when the DRT fails, set this course on your PMP arm and draw a light line in this direction from your last fix on your ship's DR track. Be sure to use a light line because when the ship changes course it will not interfere with the rest of the plot. Dead reckon your ship along this line.

To find the distance the ship travels each minute, knowing your ship's speed apply the 3-minute rule. Your plot on all contacts can be continued from this new dead reckoned course.

Don't place the time along the track until your ship should reach that point. In this manner, the location of your ship will always be indicated. Don't DR your ship more than 8 to 10 minutes ahead because there is a possibility your ship will change course and speed. For this same reason you are again reminded to draw the DR line very lightly; if your ship does change course you will not have so many confusing lines thus keeping the plot neat and clean.

A casualty to the ship's gyro is as serious as a casualty to the DRT itself. When the gyro goes out, the movement of the "bug" becomes unpredictable. On larger ships, such a failure can be immediately corrected by shifting gyros. On ships that are equipped with only one gyro it will be necessary to dead reckon your ship through successive course changes, plotting the ship's headings. In this case the ship's headings as passed from Conn to CIC will not be the true headings needed for dead reckoning because they will either be magnetic headings or compass headings. If they are magnetic headings, apply the variation to correct to true headings. This variation can be supplied from a chart of the area and should be known at all times in CIC. If CIC is receiving compass headings, they must be corrected for both variation and deviation. The latter correction may be obtained from a curve of deviations made for the magnetic compass in use.

As the deviation correction changes with each heading, a curve of deviations should be kept in CIC. This can be obtained from the navigator. You must remember also that when the gyro becomes inoperative, the radar operator will begin reporting contacts in terms of

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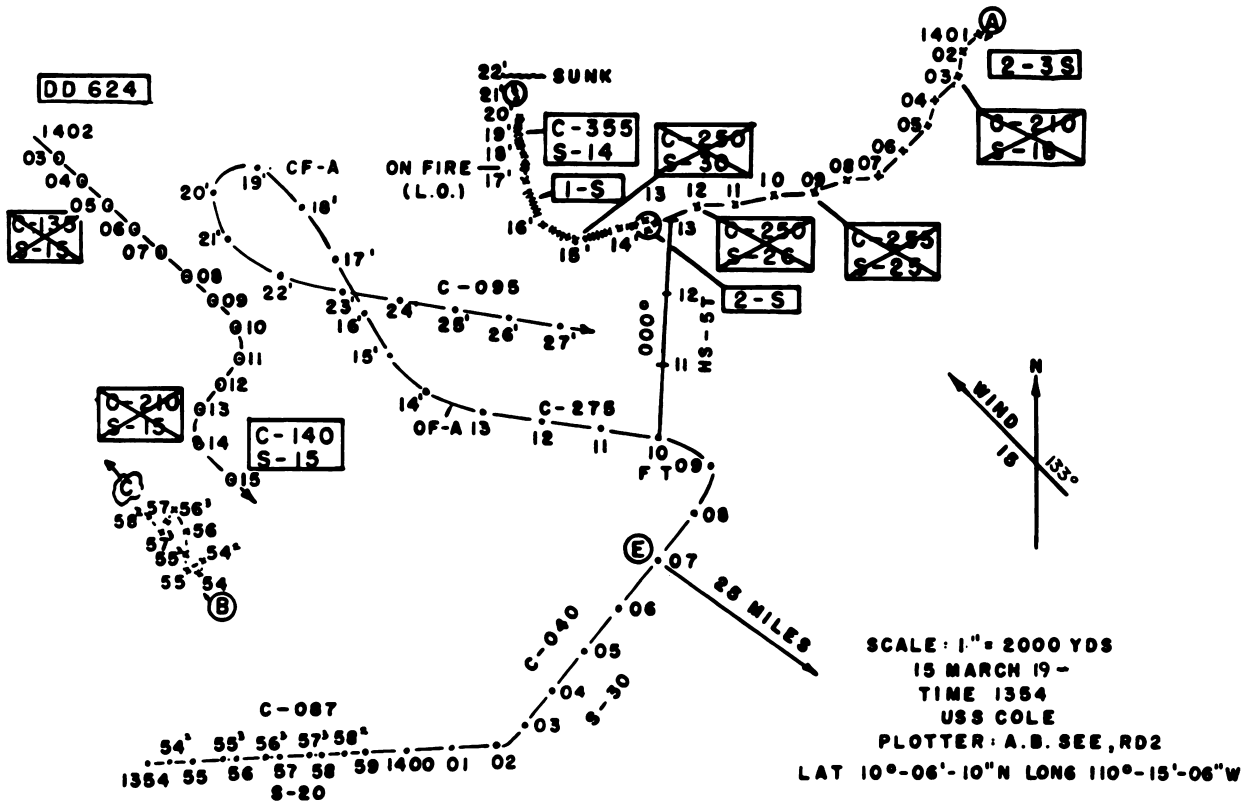

Figure 17-15.—Sample DRT plot.

relative bearings that must be converted to true bearings to continue the true plot.

Conversion of Bearings

Conversion of bearings is a very simple job if you will remember this formula—"True course (corrected true course if using magnetic or compass headings) plus relative bearing equals true bearing."

Examples—

True course	Relative bearing	True bearing
135	080	215
075	035	110
245	200	085

Notice in the last line that 245° added to 200° equals 445°, which is greater than 360°. Since a circle contains only 360°, you subtract 360 from 445, or 445 minus 360 equals 085, which is the true bearing. In every case where the sum of the true course and the relative bearing exceeds 360, subtract 360 from the sum in order to obtain the true bearing.

If you wish to convert true bearing to relative bearing, the process is just reversed. This time the formula is—"True bearing minus true course equals relative bearing."

Another casualty that might occur to the DRT is the "bug" light might go out. Simple as this casualty is, it can make tracking as impossible as a major DRT failure. Always keep a supply of spare bulbs in CIC.

A WORD IN SUMMARY

Thus far we have described how to do simple plotting on the DRT. There is more to the DRT than that discussed so far. The plotting procedure covered herein is basic—but by no means unimportant. DRT plotting is an important phase of your job as a Radarman. Radar information, plotted inaccurately, is sometimes more dangerous than no information at all, because a great deal of CIC evaluation is based on the information on your plots.

Be determined to plot as well as you know how. Remember, you are plotting for the benefit of someone else—not yourself. Be neat and write clearly—plot accurately—and, above all, be up-to-the-minute.

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(b) SURFACE

SYMBOLS	
•	Own ship (DRT plotting)
X	Unidentified or enemy contact (Stranger or Skunk)
(A)	Designation of surface contacts by letters A. B, C, etc.
○	Friendly ship
~~	Under fire (DRT plotting)
△	Radar fix (DRT plotting)
(	Right cut-on (sonar)
)	Left cut-on (sonar)
(C)	Cloud or rain squall
○	500-yard circle around plot of ship dead in the water
~~	Off screen (may be amplified to show cause of disappearance)
(J)	Jamming (placed along own track of point jammed - show direction by arrow)
	IFF only (Direction and Dist. if known)
#3	Mode number of IFF (placed beside track at point of identification)
(E)	Emergency IFF (Show direction by arrow)
(E)	Emergency IFF only (Show direction by arrow)
N	Challenged. No IFF reply.
RACKET	ECM passive D/F
	Atomic blast. Arrow indicates direction of fall out.

ABBREVIATIONS	
L	Large ship (prefaced by number)
AEW	Airborne early warning
S	Small ship (prefaced by number)
LAT	Latitude
LONG	Longitude
C	Course
S	Speed
MS	Make smoke
CS	Cease smoke
DK	Radar decoy
FT	Fired torpedoes
OF	Opened fire (add letter to indicate target)
CF	Ceased or checked fire (add letter to indicate target)
LO	Lookout report
COM	Radio report
SON	Sonar report
PIN	Enemy radar signal
VOL	Enemy guided missile signal
RAK	Intercepted electronic transmission
BTC	Base torpedo course
HS	High speed torpedoes
IS	Intermediate speed torpedoes
LS	Low speed torpedoes

Note: For antisubmarine symbols, see NWP 24

Table 17-1.—Surface plotting symbols.

QUIZ

1. What are the two sources of course and speed information that is fed through the analyzer into the DRT?
2. Name three types of controls in the DRT.
3. What scale is usually used for man overboard?
4. How is time indicated alongside your own ship's track?

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5. What are the two methods of plotting ranges and bearings on the DRT called?
6. What is the value of the surface recorder board?
7. Use the 3-minute rule and give the speed of the ships in the following examples.
   a. 600 yds. in 1 minute
   b. 1000 yds. in 2 minutes
   c. 900 yds. in 3 minutes
8. How is a contact's designation identified on the DRT plot?
9. In case of a pit log failure how can the DRT still be used?
10. How far in advance should you DR your ship in case of DRT failure?

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CHAPTER 18

NAVIGATION

CIC AND NAVIGATION

Navigation is the means by which the mariner determines his ship's position, and guides her safely from one point to another.

There are four ways of determining position in navigation:

1. By piloting, in which position is determined through the aid of bearings on objects on the earth, or by soundings (measuring the depth of water by lead line or the fathometer);
2. By dead reckoning, in which position is figured from computation of the direction and distance traveled from a known point of departure;
3. By electronics, in which position is determined by loran, radar, radio direction finders (RDF), and other devices; and
4. By celestial navigation, in which position is determined by the aid of celestial bodies: the sun, moon, planets, and stars.

In preceding chapters we have discussed the fundamentals of operating radar and interpreting radarscopes. Now let us see how this information assists the navigator. We will discuss the types of charts used, how to correct them, and how to stow them.

WHAT IS PILOTING?

If you have ever paddled a canoe, rowed a boat, or sailed a small boat on a large body of water, you probably felt more secure when you returned within sight of land. Large ocean-going ships, however, are more secure when they are cruising far out to sea. Navigational hazards increase near shore, where we have to use landmarks, short-range aids, or soundings to direct the movements of the vessel. This maneuvering of the vessel is called PILOTING. Piloting is an extremely important part of navigation. In fact, the skill with which we navigate by landmarks, navigational aids, and soundings, which we term "piloting," is so important that it behooves us to devote considerable attention to it.

HOW THE NAVIGATOR PILOTS

When a ship is moving into or out of a harbor, close to islands, reefs, or coast lines, the navigator "fixes" the position of the ship accurately by plotting visual bearings which he receives from a Quartermaster via a sound-powered telephone. The Quartermaster is stationed at the pelorus and takes his bearings from visible objects such as tanks, radio towers, lighthouses, points on shore, and the like. The navigator maintains a true track of the ship by plotting successive fixes on a chart which shows the true position of the reference points from which bearings are taken. Observation of the fixes and track of the ship enables the navigator to make recommendations to the officer of the deck as to the course the ship should follow to reach her destination safely.

The fact that position is determined by bearings taken on visual objects on the earth implies that a ship being piloted is in restricted, often dangerous, waters. In open sea there may be ample time to discover and correct an error. In pilot waters, error can quickly become ACCIDENT.

FUNCTIONS OF CIC IN PILOTING

The captain always has the responsibility for the safe navigation of his ship, according to Article 0751 of the *U.S. Navy Regulations.* However, subparagraph (h) states that the commanding officer must use available electronic devices, as appropriate, to aid safe navigation. The navigator is required, by Article 0921 of *U.S. Navy Regulations,* to maintain an accurate plot of the position of the ship by astronomical, visual, electronic (which includes radar), or other means. Article 1010 required the OOD to keep himself informed of the position of the ship, and to use such means and devices as may

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be available for detecting and avoiding the danger of grounding. Radar gives an excellent picture of coastlines, harbors, channels, buoys, and so on. It is, therefore, one of the routine functions of CIC to assist the navigator and the officer of the deck, in every way possible, to accurately determine the position of the ship when steaming in restricted waters, or when engaged in firing on targets on shore. CIC does this by maintaining a track on a chart similar to the navigator's, but uses radar instead of visual bearings and ranges. In addition, CIC uses underwater search equipment and the fathometer. Information also may be obtained visually from the lookouts, who report to CIC as well as to the bridge.

It is important to realize that radar piloting has progressed far beyond the experimental stage and is now a tried and proved means of safely navigating a ship in restricted waters, regardless of visibility. One word of caution, however: radar navigation requires much experience, both on the part of the plotters and on the part of the radar operator. Thus, it requires practice at every opportunity. In good visibility, the CIC piloting team assists the navigator in many ways. They acquire experience, and are always ready with recommendations to conn the ship should the visibility suddenly drop.

REASONS FOR KEEPING A NAVIGATIONAL PLOT

When in the vicinity of land, CIC maintains a navigational, or geographic plot. The degree of accuracy required depends on the circumstances. Keep in mind that many of the major functions of the ship (such as shore bombardment and amphibious operations) depend on an accurate knowledge of the position of the ship. It is important to keep a continuous navigational plot, when near land, for the following reasons:

1. To warn the bridge the moment the ship begins to stand into danger.
2. To supply the navigator and conning officer with radar information on short notice, as requested.
3. To facilitate identification of enemy targets.
4. To provide gun ranges and bearings for indirect-fire shore bombardment.
5. To assist in accurately directing boat waves during landing operations.
6. To navigate the ship from radar information, if ordered.
7. To assist in making landfalls, and to identify land masses.
8. To assist landing ships and craft in beach approach.

CIC also maintains a chart of the area you are operating in when outside radar range of land. Instead of using ranges and bearings to fix the position of the ship on the chart, readings from the latitude and longitude dials on the DRT are used to show the ship's approximate position. Also, periodic fixes by loran are obtained by the navigator, who notifies CIC of the position of the ship. Whenever CIC receives one of the navigator's fixes, the latitude and longitude readings on the DRT are adjusted to match those of the navigator's. The readings of both the old and the new settings of the DRT are logged. In between fixes the dead reckoning method is used.

It is emphasized that CIC keeps track of the position of the ship on a chart at all times. There are numerous reasons for this. A few of them are:

1. To aid in scope interpretation. For example, small isolated islands often appear to be ships. A check against the chart, from your present position on the chart to the target, will verify whether it is a ship or land and prevent reporting land as a ship.
2. To aid in search and rescue. CIC personnel are normally among the first to know when a plane is about to crash, or when a ship is in danger. Thus, CIC, by knowing the correct position of the ship is able to plot the position of the plane or ship in trouble, and can make immediate recommendations to the bridge.
3. As an aid in conversion plotting. By using a chart with the Geographic Reference System printed on it, you can hurriedly convert the range of a target and its bearing to the reference system, or to latitude and longitude. If the Georef system is being used on the air summary plot, you can keep the ship located on the correct position of the plot.

Before going into the methods of fixing the position of the ship by radar let us discuss the

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charts CIC has, how to stow them, and how to keep them corrected.

CHARTS

A MAP is a graphical presentation of all or a specific area of the surface of the earth. It is seen as it would appear from a great height, being flat in appearance rather than having the familiar hills and valleys we see while standing on the ground.

A CHART is nothing more than a map especially designed for navigators, which portrays some body of navigable water, together with the topography of the land adjacent to it.

The chart gives a view of the body of water as though you were hovering over the water in a helicopter and took a photograph. It is a picture, but it is not a photographic picture. It is a drawing in ink on paper. A big difference between a chart and a photograph is that the chart has standard symbols, figures, and abbreviations. These symbols, figures, and abbreviations supply information on the depth of the water, the character of the bottom and of the shore, the location of navigational aids, and other information used in navigation. Figures indicating the depth of the water are scattered over the chart, becoming more numerous in the near approaches to the land.

Unless it is on such a large scale as to render the curve of the earth unimportant, a chart is always lined with a network of parallels of latitude and meridians of longitude which locate the various features shown.

LOCATING A POSITION ON A CHART

Let us assume that you are looking at a white cue ball with an absolutely blank surface. Take a pencil and make a mark on it. Now, how can you tell anybody where, on that cue ball, the mark is located? The answer is: you cannot. There are no points or objects on the cue ball with reference to which you can locate the mark.

The earth is a sphere, just as is this cue ball. It is called the TERRESTRIAL SPHERE.

If a point were placed at the top of the ball and one at the bottom you would have two reference points. These two points are the North and South Poles located at the ends of the AXIS on which the earth rotates. By running imaginary lines (an infinite number of them, called MERIDIANS) through the poles and around the earth the earth is divided into sections, just the way an orange is divided into segments.

Now, suppose you start at the North Pole and travel along a meridian exactly half way to the South Pole. You will then be on the EQUATOR, an imaginary line running clear around the earth, which bisects every meridian, and divides the earth exactly in two halves. The half the North Pole is on is called the Northern Hemisphere; the other half, the Southern Hemisphere.

Meridians

There is a meridian for every degree around the earth -360 of them, 60 minutes (') or 3600 seconds ('') apart. There had to be some starting point for numbering these specific meridians, and most of the maritime countries decided that the starting point should be the meridian on which the Royal Observatory at Greenwich, England, is located. The Greenwich meridian is therefore numbered 0 (the Prime Meridian), and meridians run from there east and west to the 180th, which is on the opposite side of the earth from Greenwich. The complete circle formed by the 0 and 180th meridians, like the equator, divides the earth into two exact halves, one of which is the Eastern, and the other the Western Hemisphere. Every meridian runs true north and true south.

Parallels

Let us leave the meridians, now, and go back to the equator. If we draw lines parallel to the equator around our sphere we establish reference lines for north and south directions. Since these lines are drawn parallel to each other they are called PARALLELS.

The starting point for numbering the parallels is the equator, the 0 parallel. Parallels are numbered from 0° to 90° north (the north pole) or 90° south (the south pole). Every parallel runs east and west.

Viewed from just above the north or south pole, you can see that the parallels are actually circles, growing increasingly larger as they get farther from the poles. Do not forget, though, that no matter how small a circle gets, it still contains 360°.

Although the distances between the parallels appear to decrease as they get farther from the poles, actually the distances are equal and, in all cases, a degree of arc equals 60 nautical miles.

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Do not confuse distances between meridians with distances between parallels because meridians are a different story. Actual distances between meridians get increasingly less as they approach the poles. It is important that you understand these differences because it has a direct bearing on a method of measuring distance (described later in the chapter) and the geographic reference system (described in volume 2).

Latitude and Longitude

Now we have a network of imaginary lines (meridians and parallels) all the way around the globe. Every spot on the earth is located at the point of intersection between a meridian and a parallel. Every point's location is described in terms of LATITUDE (distance in degrees, minutes, and seconds of arc N. or S. of the equator, measured along the meridian of the point) and LONGITUDE (distance in degrees, minutes and seconds of arc E. or W. of 0 meridian, measured along the parallel of the point). Longitude is always from 0° to 180°. Latitude can never be greater than 90°.

One degree is approximately 60 miles, but navigation demands more accuracy than that—we must be able to designate the exact position. One degree is divided into 60' and 1' is divided into 60". Thus, a position of latitude may be 45° 15" 22" N (or S). The same system of six digits is used for a position of longitude E or W. In all reports you receive on radio nets, or read in *Notice to Mariners*, concerning navigational hazards, positions of lightships, buoys, and the like, the position is always given in both latitude and longitude.

Nautical Distance

We have already discussed the NAUTICAL MILE in a previous chapter. It is equal approximately to 1' of arc along the equator, the equivalent in length of about 1-1/7 statute or land miles. The equator is a great circle. Therefore, if 1' of arc along the equator is a nautical mile, 1' of arc along ANY great circle must also be a nautical mile. Theoretically all great circles on the earth are the same size.

This means that on any chart the MERIDIANS may be used as a distance scale. All meridians are great circles, and therefore 1' along any meridian equals a nautical mile. That 1' of LATITUDE equals a nautical mile is just another way of saying the same thing; latitude is measured along the meridians. On PARALLELS, a minute equals a mile ONLY along the Equator, the only one which is a great circle; a minute of LONGITUDE equals a mile ONLY ALONG THE EQUATOR.

Time

Time is measured by longitude from the Greenwich, England, meridian, based on the travel of the earth around the sun. 360° = 24 hours, 15° = 1 hour, and 1° = 4 minutes.

THE MERCATOR PROJECTION

From our discussion you can readily see that the surface of a sphere or globe with the chart of the world printed on it cannot be simply peeled off the sphere or flattened without being torn or stretched. All charts, therefore, distort the truth of the surface of the earth, some a great deal, and some only slightly, depending on the projection used.

There are several methods of chart projection. Different types will have different distortions. There are four principle systems of projection, each possessing certain features which recommend it for a particular purpose. These projections are: MERCATOR, POLYCONIC, GNOMIC, and LAMBERT CONFORMAL. The navigational charts that are used in CIC are the Mercator type.

Since CIC uses the Mercator projection chart, the discussion of charts throughout this text will be confined to this type. It is not necessary for you to know just how the Mercator chart differs from other types or how the chart is made. It is necessary that you know that on a Mercator projection chart all the meridians of longitude and parallels of latitude are straight lines. Thus, the Mercator chart is suitable for the DRT, and it can be set to scale so that the "bug" will move along the chart, indicating the position of your ship on the chart.

Figure 18-1 is a reproduction of a chart of the earth on the Mercator projection. Notice the heavy vertical line running through Greenwich, England. This is the 0° longitude, or prime meridian, the starting point for reading longitude. Unless the reading is exactly on this line the longitude position is always affixed with E or W at the end of the six digits.

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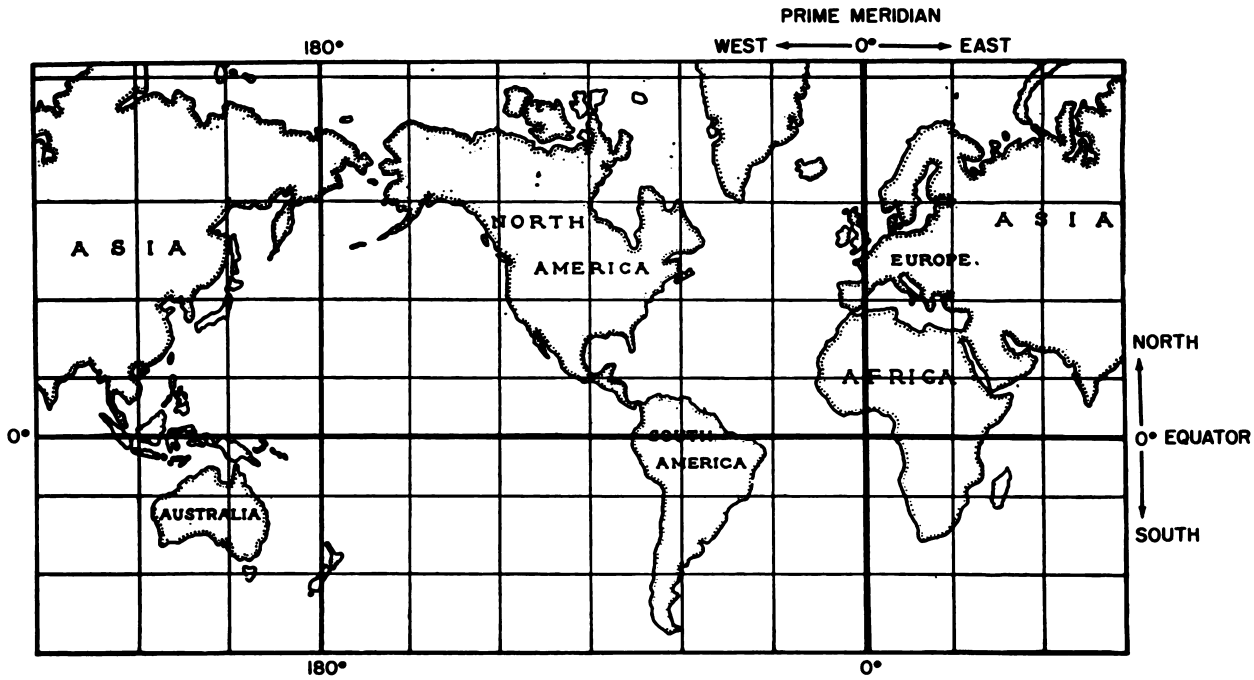

Figure 18-1.—The earth on the Mercator projection.

The heavy horizontal line is 0° latitude, or the equator, the starting point for reading latitude. Unless the reading is exactly on this line the latitude position is always affixed with N or S at the end of the six digits.

Position reports are always given with latitude first.

THE CHARTS IN YOUR CIC

Charts are used in CIC not only to assist in piloting but also in the preparation of display and in connection with performing the functions of collecting, evaluating, and disseminating tactical information. The charts CIC has on board your ship depend on the type of ship; that is, CVA, APA, LST, and so on. Because CIC provides valuable assistance in the safe navigation of the ship, an allowance of navigation charts is issued to each CIC. This allowance for each type of vessel has been apportioned on the basis of the probable operating range of the ship, and on the facilities for chart stowage. The allowance of the CIC of your ship is listed in H.O. Publication 1-PCL. In the front section of this book, list No. 7, you will find the minimum allowance for each vessel that is assigned to a unit of the Atlantic or the Pacific Fleet. This list designates only the basic minimum allowances. Your ship may carry additional charts, depending on the particular area of operation, or according to instructions issued by your type or fleet commander.

STOWING CHARTS

One of the requirements of a Radarman Third or Second is to know how to correct, how to stow, and how to keep an accurate file on charts used in CIC. On a ship using a large number of charts, it could be a full-time job.

How do you stow charts? Some DRTs have specially constructed chart drawers built in underneath. In most CICs, however, the charts are stowed in metal lockers, either in CIC, or in an adjacent passageway. Make it a point to learn where and how the charts in your CIC are stowed. You must be able to locate any desired chart at any moment.

Charts are filed in portfolios, and numbered consecutively. Separate charts stowed in drawers are also placed in numerical order. This makes it possible for any CIC personnel to locate any desired chart.

Charts must be stowed in an orderly manner in the compartments or drawers specially designed for the purpose. They are always laid

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flat, never rolled! Sometimes it may be necessary to fold them. When folding is necessary, special precautions are necessary to prevent curling at the edges.

Charts are usually removed from the portfolio boxes in which they are received on board, and stowed in drawers by portfolios in consecutive number order. However, if your ship is scheduled for an extended cruise and it is your job to file and maintain the charts, check with the navigator or leading Quartermaster to learn what charts will be needed. Then arrange the charts in consecutive order. Place them in a separate drawer so that they will be readily available. Be sure that all necessary charts are there and that they have been corrected to date. If chart correction cards N.H.O. 1278 are properly maintained you can tell immediately whether the charts are up to date. You are expected to attend to these details without special orders from the CIC officer. You are responsible also for supplying all the necessary books, tables, and equipment, even such minor items as scratch paper, pencils, forms and so on.

CHART NUMBERS

Every chart when received aboard has initials and a chart number printed in the upper left and lower right corners. The initials show the publishing agency and the number is used by the agency as a reference and filing number, as well as for ordering charts. Some of the agencies are:

1. H.O. (Hydrographic Office)
2. C.S. (Coast and Geodetic Survey)
3. B.A. (British Admiralty)
4. CAN. (Canadian)
5. DAN. (Danish)
6. GER. (German)

The navy uses another number called a consecutive number, which is inserted after the chart is received aboard. This consecutive number has no relation to the printed chart number, but is used for the naval filing system.

NUMBERING OF PORTFOLIOS

The Hydrographic Office assigns the consecutive numbers, with the idea in mind of bringing all the charts of a particular area into a group called a portfolio.

Each portfolio has a number, and this number forms the first part of the consecutive number of every chart in the portfolio. Consecutive numbers begin in each portfolio with a letter followed by four digits and in some cases a letter following the digits. Meanings of first letters follow:

1. The "A" series contains all the general charts and principal harbor and approach charts.
2. The "B" series supplements the "A" series and contains all the remaining charts on issue—charts of rivers, harbors, bays, etc.
3. The first letter of the two-letter "AW" and "BW" series means the same as in 1 and 2; the letter "W" indicates a particular portfolio.

The last two digits of the consecutive number show the number of the chart within the portfolio. For example, a chart with the consecutive number A1352 would be found in portfolio 13, which contains charts of the East Coast of the United States from Narragansett Bay to Cape Henry, including Chesapeake Bay and the Bermuda Islands. The last two numbers is the number of that chart in the portfolio. This chart is in the "A" series, showing a principal harbor or approaches. A1352 is a chart of HAMPTON ROADS.

HYDROGRAPHIC PUBLICATIONS

The prefix HYDRO means "water". Graphic is from GRAPHEIN, the Greek word meaning "to write". HYDROGRAPHIC, then, means, "writing about water"; about the watery areas of the earth, to be exact. A chart, then, is a hydrographic publication containing as much information as it has room for about the area it portrays.

Many details are omitted from charts because of lack of space. Although charts are frequently revised, conditions may have changed in a certain area since the latest revision of the chart. Detailed information concerning recent changes is obtained by the navigator through hydrographic publications. Since there are so many of these publications, only the ones of interest to the Radarman who has the job of maintaining them, will be included here.

PORTFOLIO CHART LIST

The *Portfolio Chart List,* most commonly referred to by its short title H.O. Pub. 1-PCL, is a publication furnished by the U. S. Hydrographic Office to United States vessels. On the majority

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of ships the navigator will have a copy and CIC will have a copy. This publication contains:

1. Instructions for placing into effect the chart correction card system.
2. Instructions for the use of the *Portfolio Chart List.*
3. A list of all nautical charts contained in portfolio allowances.
4. A list of the charts according to their consecutive numbers as well as in numerical chart number order. The list indicates the number and date of the latest edition of each chart.

The excerpt from Portfolio No. 57 (figure 18-2) shows you the manner in which charts are cataloged in H.O. Pub. No. 1-PCL.

H.O. Pub. 1-V (R) *Catalog of Aeronautical Charts and Publications*

The H.O. Pub. 1-N (R) index catalog is the most important of the three to the Radarman. It provides information on all nautical charts and publications available to the Navy. It is divided into three principal sections:

1. An introduction which includes a list of publications and miscellaneous charts arranged numerically within each type; for example, *Sailing Directions, List of Lights,* and *Charts of the World.*
2. A series of index charts comprising the main body of the catalog. These show limits of charts on the faces. On the reverse sides are numerically arranged lists with titles, latest edition numbers, and dates, prices, natural scale, and approximate scale in inches to the mile.
3. An appendix containing a numerical index of nautical charts and their current editions and prices, and the index chart on which each chart appears. NOTE: Charts are free to all naval units.

PORTFOLIO NO. 57

ALEUTIAN ISLANDS AND BERING SEA

ALEUTIAN ISLANDS AND ISLANDS IN THE BERING SEA; COAST OF ALASKA TO POINT BARROW; COAST OF SIBERIA FROM WRANGELL ISLAND TO MY LOPATKA, KAMCHATKA

Consec.	Chart	EDITION No.	EDITION Date	ABBREVIATED TITLE
	H.O. 0068			SEE CONSEC. AW 1
		ALEUTIAN ISLANDS		
A 5700	C.S. 8720	1	JUN 1943	KRENITZIN ISLANDS
B 5701	C.S. 9005	1	APR 1943	AKUTAN BAY
A 5702	C.S. 8861	1	MAY 1942	UNALASKA I. TO AMUKTA I.
A 5703	C.S. 9007	9	JAN 1940	UNALASKA BAY, AND AKUTAN PASS
A 5704	C.S. 9006	1	AUG 1943	CAPTAINS BAY

Figure 18-2.—Excerpt from H. O. Publication 1-PCL of Portfolio No. 57.

INDEX CATALOGS

Charts and related publications are cataloged in three volumes:

H.O. Pub. 1-N (R) *Index-Catalog of Nautical Charts and Publications*

H.O. Pub. 1-L *Catalog of Loran Charts and Publications*

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How to Use the Catalog

The Radarman uses the Catalog for the most part in selecting a chart to be used in proceeding from one point to another.

The world has been divided arbitrarily into separate geographic areas, and each area is represented graphically on an index chart. Limits of these areas are shown on a chart of the world, Index AX, and labeled with the letter of another index chart on which the nautical charts of the area appear. To find the chart of a particular area, consult Index AX for the proper index chart. The chart number can be found on the face of the index chart within or next to the limits of the exact area covered, or in the case of large scale plans, next to the abbreviated name of the location. Exact title of the chart can be found on the reverse side of the index chart in numerical order. If the number of the desired chart is known, but not the area, consult the appendix which includes a reference to the index chart on which each chart can be found.

Correction of the Catalog

Additions and changes to the catalogs can be obtained from the Monthly Information Bulletins and Bimonthly Index to H.O. Pub. 1-V(R). The Monthly Information Bulletin contains a listing of new nautical publications and charts and their limits, new editions, dates, prices, cancellations, and withdrawals. All Navy ships receive a copy of this bulletin. The Index to H.O. Pub. 1-V(R) contains a listing of all aeronautical charts and publications and indicates the latest editions. In addition, when corrections become excessive, corrected individual index charts are printed. Corrections to the catalogs should be made promptly and a record thereof indicated in the appropriate column on the page "Record of Corrections."

Titles

Titles listed on the reverse side of the index charts are the same as those used on the charts. The main title of the specific area is the one given. Alternative names and general locations are enclosed in parentheses.

NOTICE TO MARINERS

Only latest editions of charts are issued to ships. When issued they have been corrected by hand so as to include information published in *Notice to Mariners* between the date the chart was printed and the date it was issued. This fact is indicated by a stamp on the face of the chart, as shown in figure 18-3. Corrections subsequent to the date of this stamp must be obtained from weekly issues of *Notice to Mariners*. Notice to Mariners is published weekly in two parts by the Hydrographic Office. Part I (Western Hemisphere) and Part II (Eastern Hemisphere). *Notice to Mariners* contains such information as aids to navigation of the United States; lists of destroyed lights; notices of change pages for *Sailing Directions;* special notices, as of sales agency cancellations and additions, and the like; notices of new Hydrographic Office and Coast and Geodetic Survey charts; corrections to *Radio Aids to Navigation* (H.O. 117), H.O. and Coast Guard Light Lists, Nemedri and other special navigational warning messages; and chart correction lists, arranged by issuing office number and by chart portfolio consecutive number.

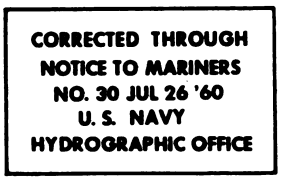

Figure 18-3.—Sample of how the Hydrographic office stamps a chart.

How to Use the 1-PCL

Aboard ship, charts are filed by portfolio in consecutive number order. The 1-PCL is used to determine the consecutive number.

Let us take an example and see how to find the consecutive number of a chart. You receive a chart aboard, and looking at the lower right side of the chart, you see the initials U.S.C. & G.S. and the number 1210. The initials stand for United States Coast and Geodetic Survey. The number is that agency's reference and filing number.

To find the consecutive number, take the 1-PCL and open it to the Numerical Index for Coast Survey Charts. (If the chart had H.O. instead of U.S.C. & G.S. you would then have to turn to the Numerical Index for Hydrographic Office Charts. Or if the initials were B.A., then you would go to the Numerical Index for British Admiralty Charts.) After turning to the numerical index for

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Coast Survey Charts, notice that the chart numbers are arranged in numerical order. Follow the numerical chart list until you come to the number you are looking for (1210); in the adjacent column you will find the number A1295.

The number A1295 is the consecutive number. The first two numerals, 12, show that the chart is to be filed in Portfolio 12. The second two numerals, 95, indicate the order in which the chart is to be filed in that portfolio.

Write this number on the outside of the chart where it can be seen readily when leafing through the chart portfolio. This practice expedites locating a particular chart in a portfolio.

In addition to marking this number on the chart, you must make out a chart correction card. A supply of printed chart correction cards, size 5" x 8" (Form N.H.O. 1278), is furnished to each vessel.

The following procedure is used in setting up and maintaining this card system. Using the H.O. Pub. 1-PCL, prepare a card for each chart, entering the following information on each card (by typewriter if possible):

1. In the appropriate column, the consecutive number, (In our example you would enter A1295.)
2. Chart Number (U.S.C. & G.S. 1210)
3. Edition number (6)
4. Edition date (Feb. 1943) The edition number and date can be found either in the 1-PCL, or on the chart itself. On foreign charts, where no edition number is shown, the date in the "Edition Date" column is the first H.O. print date, which should be entered in the "Edition Date" space.
5. The latest *Notice to Mariners* number through which the chart is corrected (No. 8, of 3 Sep 1951). The Hydrographic Office inserts a slip in each chart portfolio and in each automatic shipment of new charts and new editions, showing the *Notice to Mariners* number and date through which the charts are corrected. Individual charts sent by hydrographic distributing offices, as in our example, are stamped with that information.
6. The title of the chart (Martha's Vineyard to Block Island). If the title of the chart is too long to insert in the space available, abbreviate it or use a short descriptive title.

Now you are ready to file the card. Cards are filed in consecutive number order, with dividing cards carrying portfolio numbers inserted between portfolios.

CORRECTING CHARTS

The Hydrographic Office issues a *Notice to* Mariners every week to keep you abreast of all the changes necessary since a chart or book was last revised. Some of the information in the publications you have just read about, as well as the information on your charts, can quickly get out of date. Lights are destroyed or replaced, new lights are established, the characteristics of lights are changed, channels are dredged, and sunken wrecks are discovered or known ones removed.

HOW TO MAKE CORRECTIONS

From time to time CIC receives copies of *Notice to Mariners*. Of course these publications cannot be delivered at sea, so you usually have a number of notices to pick up when you reach port.

How do you handle corrections? You could go ahead, just grabbing here and there and scribbling corrections at random, hoping that you got them all, but when using your charts, you would never be sure all corrections had been made.

To ensure uniformity, a procedure for correcting charts is followed, using the standard symbols (H.O. Chart No. 1). The charts affected by a *Notice to Mariners* are indicated in bold-face type at the bottom of each paragraph. Before actually correcting any charts, the first thing to do is "Charge the Card."

Consult the Chart Correction List near the front of the *Notice to Mariners*. Figure 18-4 is a Chart Correction List for N.M. 4 of 1960 (part I). Notice that the charts are listed in consecutive numerical order with an adjoining chart number column, followed by the paragraph number that is to be corrected.

Go down the list checking against the chart correction cards. If you see a card number shown on the list, pull it. Write the year of the *Notice to Mariners*, the number, and paragraph number, on the chart correction card. To show that the card has been charged with the paragraph number in the Notice to Mariners, place a check mark after the paragraph number. If more than one paragraph number is listed for a chart, use a separate line for each paragraph number on the correction card.

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Chart Correction List for N.M. 4 of 1960 (Part I) According to Consecutive Numbers

For Navy Use

Consecutive No.	Chart No.	Paragraph No.	Consecutive No.	Chart No.	Paragraph No.
AW11	H.O. 5761	394.	B1451	C.S. 1257	379, 380.
AW12	H.O. 957	394.	B1452	C.S. 586	379.
AW13	H.O. 958	394.	B1453	C.S. 587	380.
BW87	H.O. 1071	394.	B1460	C.S. 1263	382.
A1102	H.O. 1109	350.	B1467	C.S. 1267	383.
B1103	H.O. 2716	350.	A1816	H.O. 2650	387.
B1104	H.O. 2686	350.	B1817	H.O. 2106	387.
A1105	H.O. 1110	353.	B1818	H.O. 2772	386.
A1118	H.O. 6611-L	355.	A1829	C.S. 901	389.
A1119	H.O. 1067	352.	A1834	C.S. 904	388.
B1134	H.O. 1076	349.	B1848	C.S. 929	389.
A1200	H.O. 525	355.	B1862	H.O. 1004	380.
A1214	H.O. 2129	355.	B1864	H.O. 366	390.
B1229	H.O. 610	357.	B1875	H.O. 1165	391.
A1230	H.O. 2133	356, 357.	B2018	H.O. 5437	392.
B1231	H.O. 2134	357.	B2074	H.O. 970	393.
A1242	C.S. 1000	358, 364, 366, 368.	A2079	H.O. 1503	393.
			A2112	H.O. 1331	394.
B1244	C.S. 70	358, 364, 366.	A2117	H.O. 1332	394.
			A2118	H.O. 1674	394.
A1246	C.S. 1106	358.	B2130	H.O. 5683	395.
B1256	C.S. 1203	358.	A2144	H.O. 5281	397.
B1259	C.S. 71	358.	A2145	H.O. 5286	397.
A1261	C.S. 1204	358.	B3132	H.O. 4047	420.
A1279	C.S. 246	421.	B4051	H.O. 9540-50	347.
A1303	C.S. 1215	364.	B4052	H.O. 5715	347.
B1314	C.S. 218	360.	A4072	H.O. 5612	348.
A1316	C.S. 1213	363.	B4074	H.O. 9540-20	348.
B1319	C.S. 361	361.	A4644	H.O. 4827	420.
B1320	C.S. 220	362.	A5116	H.O. 5948	398.
A1324	C.S. 223	363.	B5319	C.S. 5147	400, 421.
B1330	C.S. 285	365.	A5363A	C.S. 6151	404.
B1336	C.S. 1216	366.	B5365	C.S. 6153	406.
A1340	C.S. 294	421.	B5367	C.S. 6155	407.
A1344	C.S. 1109	368.	A5392	C.S. 6300	408, 409.
B1346	C.S. 1221	367.	A5395	C.S. 6380	408.
A1347	C.S. 1222	368, 369.	B5398	H.O. 5629	408.
A1349	C.S. 78	368, 369.	B5491	H.O. 1769	408, 409.
B1353	C.S. 452	370.	B5402	H.O. 2570	408, 409.
B1369	C.S. 494	369.	B5408	H.Q. 1278	410.
A1400	C.S. 1227	368.	B5409	H.O. 1774	410.
B1421	C.S. 447	321.	B5412	H.O. 5367	411.
B1425	C.S. 685	373, 421.	A5433	H.O. 5361	412.
B1425	C.S. 686	421.	A5448	H.O. 1767	412.
B1428	C.S. 1245	376.	B5567	C.S. 8255	413.
B1431	C.S. 1247	377.			

Figure 18-4.—Chart correction list for NMN.4 of 1960 Part I according to consecutive numbers.

After all entries have been made on the cards, correct those charts which are in active use. Further entries are made on the cards to show the date the correction was made, and the initials of the person who made the correction.

When a chart has been corrected and initialed, draw a light line through the paragraph number in the *Notice to Mariners* with a red pencil. This saves confusion later, and shows that the chart has been corrected.

In correcting charts to which numerous corrections have accumulated, it is more practical to make the latest correction first and work backwards, as many late corrections may cancel earlier corrections.

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After correcting the charts and initialing the cards, file the *Notice to Mariners*. Notices to Mariners are kept in a special folder and retained for further use.

The greatest advantage of the card correction system is that it is a ready reference to tell if the chart you want to use is up to date. For example, suppose your ship normally operates around Norfolk, Virginia. Naturally you would make all entries on the correction cards and correct all charts of that area immediately. Now suppose your ship is scheduled for a trip to Newfoundland. Break out the cards for the charts of the area to which you are going. By inspection of the card you can tell if the charts are up to date. If one indicates there is a correction to be made it will tell you the *Notice to Mariners* to be used to make the correction. This saves many hours of work correcting charts from every Notice to Mariners—charts that your ship may never use. Thus, if it is your responsibility to maintain the charts it is important that you check the cards against the 1-PCL to assure that a card has been prepared for each chart in each portfolio on board.

Normally, the commanding officer will determine and issue instructions as to which charts (portfolios) are to be kept corrected at all times. If you don't have this information ask your CIC officer to get it for you.

THINGS TO REMEMBER ABOUT CHART CORRECTING

1. All corrections are made in ink.
2. Standard chart abbreviations are used. H.O. Chart 1 contains the standard symbols and abbreviations to be used. C.S. 0001 and *Dutton's* also list symbols and abbreviations. In addition, be particularly careful to make your hand corrections conform to the style of matter already on the chart.
3. Corrections in writing should be kept clear of the water, as much as possible, unless the objects referred to are on the water.
4. When inserting written corrections, take care not to obliterate information already on the chart.
5. When "notes" are to be inserted (such as cautionary, tidal, and the like) they should be written in a convenient but conspicuous place where they will not interfere with other details.
6. The amount and character of information to be inserted on a chart should be in accordance with that already printed on such charts. This means, for example, that on coast charts full particulars of lights and fog signals are inserted wherever possible, omitting minor details of lights and fog signals of harbors. On charts of smaller scale than coast charts, lights and fog signals of harbors are not inserted at all, and particulars of other lights and fog signals are lessened as the scale of the chart decreases. On ocean charts, only lights visible 15 miles or more are inserted, unless otherwise stated on the chart. On coast charts, inner harbor buoys and beacons are not inserted. On small scale charts insert only the outer buoys.
7. Charts issued by the Hydrographic Office are not corrected for temporary changes.
8. On large scale charts the year date should be inserted for wrecks, reported shoals, dredged channels, depth of water over bars or in shifting channels, and against reported irregularity of lights.
9. Temporary changes may be indicated in pencil, referencing the appropriate *Notice to Mariners* beside each. They are erased when notice has been received canceling them.
10. The Hydrographic Office collects and distributes, by radio, all hydrographic information involving danger to a vessel through collision or a deficiency in aids to navigation. This information is afterwards confirmed or otherwise acted upon by *Notice to Mariners*.

ORDERING CHARTS

All requisitions or orders for charts and publications originating from vessels, activities, or other units of the U.S. Navy west of the Mississippi (except Gulf of Mexico and Canal Zone areas) or in the Pacific area, are addressed to the Hydrographic Distribution Office, United States Naval Supply Depot, Clearfield, Ogden, Utah. Orders from all other areas are addressed to the Hydrographic Distribution Office, United States Naval Supply Depot, Philadelphia 20, Pa. Branch Hydrographic

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Offices stock and issue nautical charts and publications in limited quantities to ships or other activities in their area. OPNAV INSTRUCTION 5604.4 outlines procedures by which all naval and Marine corps commands may obtain required nautical and oceanographic charts, other related navigational charts, publications, and periodicals.

Be careful to observe the following procedure in submitting requests:

1. Consult the *Portfolio Chart List* or the *Index Catalog* before ordering to ensure that the charts and publications are on issue by the Hydrographic Distribution Offices. The Introduction to the *Index Catalog* lists the publications of the Hydrographic Office which are issued by the Hydrographic Distribution Offices.
2. Routine requests for material should be ordered as far in advance as possible. Specify a realistic deadline delivery date (calendar date) and priority. Refer to OPNAV INSTRUCTION 5604.4.
3. Furnish proper mailing address, but be certain address given does not violate security regulations.
4. Order by chart number instead of by consecutive number. The initiating activity must:
   a. Assign a requisition number to each requisition.
   b. Submit an original and five copies to the issuing activity.
   c. Prepare a separate requisition for each of the following types of material ordered:
      (1) Nautical charts (HO, CS, BA, DAN., CAN., and the like)
      (2) Nautical publications and periodicals.
      (3) Classified charts and publications; classified publications bearing register numbers are issued by the Director, Naval Communications, Registered Publication Section.

Figure 18-5 shows a properly prepared requisition, DD-1149.

RADAR PILOTING TEAM ORGANIZATION

Perfect teamwork is essential to good radar piloting and only practice can make perfect. Your CIC officer will consider the capabilities and limitations of his crew to ensure that the right man is in the right job for this important function of CIC. As a Radarman Third or Second you may be the senior man; the CIC officer will ask your advice on the placement of the personnel during special sea and anchor detail.

Under conditions of good visibility, piloting is handled by the navigator on the bridge. CIC will also pilot the ship by radar information, to gain experience. It is apparent that only the repeated demonstration of precise piloting by CIC during these conditions of good visibility, when CIC's performance can be measured against that of the navigator, will convince the commanding officer that he can trust CIC to pilot the ship under conditions of poor visibility. Even when CIC is piloting the ship through comparatively dense fog, however, some visual information will usually be available to the CIC radar piloting team. Generally, buoys will be passed close enough aboard to be spotted and identified by well-trained lookouts. Lookouts are instructed in recognition and are responsible for passing all available information on buoys to CIC via the JL sound-powered telephone circuit. The lookout report consists of: the type of buoy, (spar, can, nun, bell, gong, whistle, lighted, or combinations of these, depending on their shape, color and audio aids); the approximate range; and the relative bearing. Thus, as a plotter you should be able to recognize the symbol printed on the chart that designates each of these various navigation aids. A study of Chart H.O. 1 will aid in picking these out on the chart without difficulty.

PILOTING TEAM PERSONNEL

The CIC team should utilize the best means available for collecting, evaluating, and disseminating the information necessary for piloting the ship. The team should have just enough men to do the best job possible, and no more, for "too many cooks spoil the broth".

The size of the radar piloting team may be below the optimum size because of the lack of equipment and/or men. The following discussion presents the possible members of a radar piloting team, their duties, and their problems.

CIC Officer

Radar piloting is such an important task that the CIC officer will undoubtedly arrange to be in CIC at all times during an operation. He must avoid performing any tasks other than coordinating the activities of the team, and

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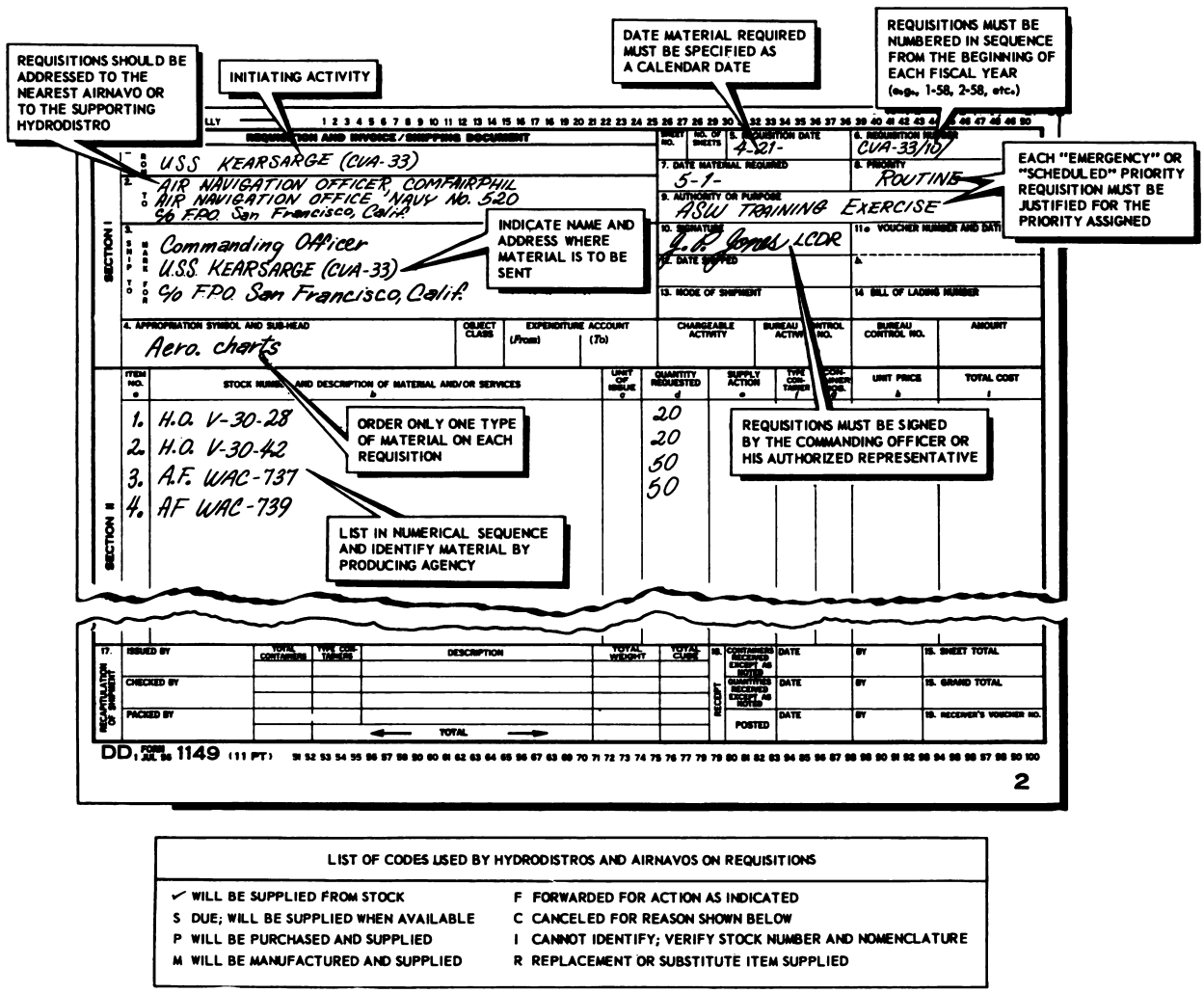
REQUISITIONS SHOULD BE ADDRESSED TO THE NEAREST AIRNAVO OR TO THE SUPPORTING HYDRODISTRO
INITIATING ACTIVITY
DATE MATERIAL REQUIRED MUST BE SPECIFIED AS A CALENDAR DATE
REQUISITIONS MUST BE NUMBERED IN SEQUENCE FROM THE BEGINNING OF EACH FISCAL YEAR (e.g., 1-58, 2-58, etc.)
EACH "EMERGENCY" OR "SCHEDULED" PRIORITY REQUISITION MUST BE JUSTIFIED FOR THE PRIORITY ASSIGNED
INDICATE NAME AND ADDRESS WHERE MATERIAL IS TO BE SENT
ORDER ONLY ONE TYPE OF MATERIAL ON EACH REQUISITION
REQUISITIONS MUST BE SIGNED BY THE COMMANDING OFFICER OR HIS AUTHORIZED REPRESENTATIVE
LIST IN NUMERICAL SEQUENCE AND IDENTIFY MATERIAL BY PRODUCING AGENCY
USS KEARSARGE (CVA-33)
AIR NAVIGATION OFFICER, COMFAIRPHIL
AIR NAVIGATION OFFICE, NAVY No. 520
C/O F.P.O. San Francisco, Calif.
Commanding Officer
U.S.S. KEARSARGE (CVA-33)
C/O F.P.O. San Francisco, Calif.
4-21-
CVA-33/10
ROUTINE
ASW TRAINING EXERCISE
G. P. Jones, LCDR
Aero. charts
1. H.O. V-30-28 20
2. H.O. V-30-42 20
3. A.F. WAC-737 50
4. AF WAC-739 50
DD, FORM 1149 (11 PT)
2

LIST OF CODES USED BY HYDRODISTROS AND AIRNAVOS ON REQUISITIONS	
✓ WILL BE SUPPLIED FROM STOCK	F FORWARDED FOR ACTION AS INDICATED
S DUE; WILL BE SUPPLIED WHEN AVAILABLE	C CANCELED FOR REASON SHOWN BELOW
P WILL BE PURCHASED AND SUPPLIED	I CANNOT IDENTIFY; VERIFY STOCK NUMBER AND NOMENCLATURE
M WILL BE MANUFACTURED AND SUPPLIED	R REPLACEMENT OR SUBSTITUTE ITEM SUPPLIED

Figure 18-5.—Preparation of DD form 1149.

evaluating information that cannot be evaluated by other members of the team. He may sometimes wish to communicate with the bridge directly, rather than through the JA talker; a selector switch with a handset is provided for this purpose.

CIC JA Talker

A JA talker by the side of the CIC officer is highly desirable. The primary function of the JA talker is to receive communications from the bridge. By so doing, he eliminates the necessity for the CIC officer to wear a headset. The JA talker relays communications from the bridge JA talker to the CIC officer immediately.

Assistant CIC Officer

In addition to radar piloting, the other functions of CIC, particularly the tracking and reporting of surface contacts, must be performed. In order to ensure that these are not neglected the CIC officer should have an able assistant, either a CIC watch officer or the leading petty officer. The assistant CIC officer should be placed in charge of the nonpiloting functions of CIC.

The assistant CIC officer coordinates the activities of the radar repeater search operator, the status board keeper, the north DRT plotter, (if used), surface plotter, and the air picture (if manned).

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The assistant CIC officer uses a separate repeater, if available, and tracks all contacts on the PPI scope for spot indications of CPA. As you know, an estimate of course and speed can also be obtained directly from plots on the PPI.

The assistant CIC officer uses the PPI mostly as a check against the surface plot, and normally uses his estimates only when the surface plotter has too many contacts to handle satisfactorily.

The assistant CIC officer observes the surface plot, surface recorder board, and the PPI plot. He makes routine reports to the bridge talker, and informs the CICO of unusual developments.

The assistant CIC officer also has means of communicating (by using a sound-powered telephone selector switch or communication console) with the radar operator or the radar repeater (search) operator, surface recorder, north DRT plotter, and surface plotter via the 25JS sound-powered telephone circuit.

Radar Repeater (Search) Operator

The radar repeater (search) operator searches for surface contacts and reports ranges and bearings of contacts over the 25JS circuit.

Status Board Keeper (Surface Recorder)

The status board keeper, or surface recorder, records the ranges, bearings, courses, speeds, and CPA's of contacts received from the radar repeater (search) operator and surface plotter.

Surface Plotter

The surface plotter performs the duties explained in chapter 14. He plots contacts, determines their courses, speeds, and CPA's.

Lookouts

The number and location of lookouts vary with the ship; they are all on the JL circuit, and they all report to CIC. Well-trained lookouts can make themselves very valuable by identifying buoys, giving approximate range and bearing, and by identifying contacts that appear on the scope.

JL Talker (CIC)

The JL talker must coordinate the efforts of the lookouts, evaluate their reports, and sometimes plot pertinent information on the DRT. Most of the time, the talker only relays information to the north DRT plotter and surface recorder and surface plotter.

If a petty officer has been responsible for lookout training, it might be an excellent idea to give emphasis to the lookouts' importance by placing him in charge as the JL talker.

JL Talker (Bridge)

The JL talker on the bridge need not be an experienced person. He relays all lookout reports to the OOD.

Fathometer Operator

Regardless of whether the navigator is obtaining fathometer information, CIC should do so. The fathometer operator normally is a Quartermaster reporting on a JW phone circuit. On many ships, the navigator's bearing talkers are also on the JW circuit, which makes it easier to compare radar and visual information for training purposes. The CIC JW talker maintains a log of the fathometer readings and visual bearings taken by the navigator's bearing takers. This information is used for reference by the CICO and DRT operator.

Sonar Personnel

On ships having sonar equipment, sonar information can sometimes be used. Sonar reports are conducted to CIC on the 61JS sound-powered telephone circuit.

Fire Control Radar Operator

The choice of radar repeaters used to determine own ship's position depends primarily on the equipment in CIC and the availability of fire control radar. Three sets of ranges and bearings are optimum for most radar piloting purposes, and fire control radars provide this information most accurately. On cruisers it is desirable to have gunnery department personnel man four fire control radars, two on each side of the ship. On carriers and destroyers, limitation of fire control equipment may prohibit the availability of more than two radars. Smaller ships and auxiliaries may have only one such radar.

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CIC Radar Repeater (Pilot) Operators

Depending on the fire control radar equipment on the ship, enough additional radar repeaters should be manned in CIC to provide the facilities for three radar operators to consider three separate targets, even though the three targets are on the same side of the ship. Therefore, cruisers need only one repeater (VF if available) to supplement the fire control radar. A radar repeater should always be available for the CIC officer to compare radar information with chart information, and to facilitate the assignment of specific targets to the fire control and radar repeater operators. The fire control radars should be manned by their regular personnel. The operations officer must enlist the cooperation of the gunnery officer so that he can use both the fire control radars and the radar operators. The radar operators used in determining own ship's position should all be on the 22JS circuit, if possible. The CIC officer should have a 22JS handset so that he can assign targets to the various operators to ensure that their efforts are coordinated.

Normally, the CIC officer will hold a conference with all radar operators before entering a port or conducting radar piloting. During the conference they will study the charts to be used, and determine the most desirable targets to use in establishing the radar fixes. Alternate targets should be designated. Other problems should be anticipated at this time so that they may be analyzed carefully and solved in advance.

South DRT Plotter

The south DRT plotter plots the ranges and/or bearings used to determine the ship's position. Since the radar operators report to him, it is preferable that he be one of the senior petty officers.

He should obtain radar fixes once each minute, if possible, by as many standard methods as are appropriate to the availability of suitable radar targets. Should fixes every minute not be feasible, he spaces the intervals as appropriate to the situation, but attempts to obtain one fix at least every 3 minutes. The south DRT plotter always dead reckons the ship's position between fixes.

The south DRT plotter must calculate set and drift, compare the results with the navigator, then apply set and drift to recommended course and speed. He compares fathometer readings with depths indicated on the chart. This information can be used to verify a weak fix. When possible, the south DRT plotter obtains visual bearings and ranges for comparison. The CIC officer verifies this information before sending it to the bridge.

Radar Navigation Bearing Log Keeper

The radar navigation bearing log keeper maintains an accurate record in the radar navigation bearing book of all radar fixes, including time, target, bearing, and range. He records in this book all recommendations to the bridge. Entries are made in the CIC log at the same time. In order to maintain the navigation bearing log the keeper must be on the same phone circuit as the south DRT plotter and radar operators.

PLOTTING OWN SHIP'S TRACK BY RADAR FIX

Before a ship leaves or enters port, or steams into restricted waters, the navigator studies the charts and various other publications. He then lays down a safe course for the ship. He discusses the proposed track with the commanding officer. As soon as possible, the CIC officer confers with the navigator. Items of interest to the CIC officer include positions where the navigator desires to change speed, turning reference points, desired time of arrival at destination, points he plans to use for visual plotting, and expected current. The CIC officer should have the track copied on the appropriate charts. He should then carefully study the chart, noting such things as hazards to navigation and ranges. He should plot in slide lines, danger bearings, the point on the track where the ship should be each minute, and where the ship will be when he should change to the next chart. Next, the CIC officer should hold a conference with his radar operators to determine the most desirable targets to use in establishing the radar fixes. Alternate targets should be designated. Other problems should be anticipated at this time so that they may be analyzed carefully and, as far as possible, solved in advance. If your ship has any RPD photographs, which are scale models of the terrain, they should be studied to see what targets the radar will receive. All radar piloting personnel should carefully study the charts.

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When special sea and anchor detail is set, the radar piloting team should be ready to go into action.

COMPARISON BETWEEN MOVING AND FIXED OBJECT TRACKING

In chapter 17 we discussed tracking moving objects on the DRT. We were not concerned with the position of our ship on the earth, we merely wanted to know where we were relative to other ships—ships in our own formation, or strange contacts.

Consequently, we maintained a plot of the tracks of own and other ships without reference to latitude, longitude, or nagivational charts. To plot the track of own ship relative to fixed charted objects on the earth, we must use a chart of the area in which we are operating, and do our plotting directly on the chart.

Then when we plot a position of own ship, we have a picture of the position of the ship in true relationship to all navigational aids and hazards shown on the chart.

Small area Mercator charts are used on the DRT in radar piloting. There are two important points about these charts that must be considered:

First, when the chart is secured on the top of the DRT table, the parallel motion protractor must be aligned north and south with the compass rose on the chart. This is necessary to prevent an error in plotting of bearings.

Next, the ruler scale of the parallel motion protractor must be the same as the scale of the chart. This is necessary to prevent an error in plotting of ranges.

MEASURING DISTANCES ON A CHART

Distance is measured on a chart by using the latitude scale only in the latitude where the distance is desired. This is because minutes of latitude become longer as latitude increases, producing corresponding variance in the distance scale. Remember, each minute of latitude represents ONE NAUTICAL MILE IN THE LATITUDE OF THE SCALE. Thus, if the distance between two points on the same meridian is desired, the problem is simple. The difference of latitude in minutes is the distance in nautical miles. Distance along a line not parallel to the meridians must be measured by setting the dividers along the scale and then STEPPING OFF the line.

Longitude cannot be used to measure distance on a chart. Although the meridians on the chart appear to be parallel, on the surface of the earth they converge to a point at the poles. So you saw before, it is for this reason that on a chart it is only at the equator that a minute of longitude equals one nautical mile.

As stated before, most of the Mercator projection charts you will use on the DRT cover a very small range in latitude and are made for a small area coverage. The change of the Mercator length of a minute of latitude within so small an area can be disregarded. On most of these charts, there is a printed scale of miles for use over the entire chart. Instead of using the latitude scale you can measure the distance from a distance scale.

Frequently the scale printed on the chart is too short. If you wish to measure a 4-mile distance but the scale reaches only to 2 miles, it will be necessary to extend the scale.

Once the scale is extended, there are three common ways to measure the extended distance. The first is with an ordinary pair of 7-inch dividers or drawing compass. The second is with a 16-inch beam compass which in general appearance somewhat resembles a football goal post. Both posts are movable; however, one must remain stationary while moving the other, so that the distance between posts can be opened or closed. The movable post can be locked into place with a thumbscrew. The operator places the posts at the two places on the chart where the distance apart is desired, locks the thumbscrew, and then transfers the posts to the extended scale on the chart, and reads the distance. Conversely, when determining own ship's position the radar operator determines a range to a known point. This range is relayed to the plotter by sound-powered telephones. The plotter than spreads the beam compass the desired length by using the scale. He tightens the thumbscrew, then places the pointed end of the beam compass on the object the range is taken to and swings an arc. By swinging arcs or radar ranges to at least three known points, separated more than 30°, own ship's position will be established.

The third method is as already explained, that of making a duplicate of the extended scale on masking tape and sticking it directly on the parallel motion protractor rule. Measurement can be taken directly off the rule. This system is very good for taking a bearing and range to a single object and for dead reckoning own

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ship, but not so good as the beam compass, since it is rather hard to swing a true arc.

CHART SCALES

The size of the area portrayed by a chart varies considerably, according to the SCALE of the chart. The larger the scale, the smaller the area represented; from which it necessarily follows that large-scale charts show areas in greater detail. In fact, many features which appear on a large-scale chart will not show at all on a small-scale chart of the same area.

The scale on which a chart is drawn generally appears under its title in one of three ways, as follows:

$$1 \text{ to } 5000,\ 1{:}5000,\ \text{or } \frac{1}{5000}$$

These figures mean, in effect, that an actual feature is 5000 times as large as its representation on the chart; or, expressing it in another way, that an inch, foot, or yard on the chart means 5000 inches, feet, or yards on the earth's surface. The larger the figure which indicates the proportion of the scale, the smaller the scale of the chart. For instance, a chart with a scale of 1:5000 is on a much larger scale than one whose scale is 1:45,000,000.

Greater caution must be exercised when working with small-scale charts than when working with those on a large scale. A small error, which may be only a matter of yards on a large-scale chart, could amount to miles on a chart depicting a much more extensive area. When navigating the approaches to land, only charts on the largest scale are used.

Adjusting DRT to Chart Scale

To use a chart on the DRT, you generally have to convert the scale to yards per inch to set the VERNIER DIALS in the DRT so that the DRT bug will track properly. Dividing the chart scale denominator by 72,000 (the number of inches in a nautical mile) will give the chart scale in nautical miles per inch. Dividing the larger figure by 36 will give the chart scale in yards per inch. If the chart scale is not printed, measure along the latitude scale 10 inches, and count the number of miles to the nearest tenth; then point off one place to the left. Thus, if there are 11.7 miles in a 10-inch interval, the scale of the chart is 1.17 miles per inch.

The normal procedure for adjusting the DRT to the proper scale follows. See figure 17-4 to follow the discussion.

1. Determine the scale of the chart. For example, the scale is $\frac{1}{80,000}$.
2. Divide 80,000 by 36. The result is 2,222 yards per inch.
3. From the red, white, or green scales, select the white because its range is 2,000 yards to 8,000 yards.
4. Make sure the vernier dial is set exactly at zero.
5. The scale is now 2000 yards per inch.
6. This leaves 222 yards to be cranked in.
7. One complete turn of the vernier equals 500 yards when set on the white scale.
8. There are 25 digits on the vernier; thus, each digit equals 20 yards.
9. To get 222 yards, turn the vernier to number 11.
10. Be sure to set both verniers exactly the same.

Now the DRT is set on the proper scale and ready for tracking. Check the alignment of the chart on the DRT plotting surface, and position the "bug" in the ship's location, then turn on the motors and the "bug" will automatically show where your ship is at all times. Set and drift are not considered at this point.

SOUNDINGS

Scattered all over the watery area of any navigational chart are many tiny figures, each representing the depth of water (generally the depth at MEAN LOW WATER) in that particular locality. Depths on some charts are given in feet, on others in fathoms. A notation under the title tells you which—either "Soundings in feet (or fathoms) at mean low water."

In addition, most charts contain dotted lines, called FATHOM CURVES, marking the limits of areas of certain depths.

AIDS TO NAVIGATION

Aids to navigation are indicated on a chart by appropriate symbols. (See H.O. Chart-1 or Quartermaster 3 & 2.) As much information as possible is printed in standard abbreviations near the symbol. For instance, look at the light on Castle Hill, on the W point of Newport Neck

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(fig. 18-6). Printed near the light symbol is the following: FL R 30 sec 40 ft 10 m. This means the light is red flashing light, flashing every 30 seconds. It is 40 feet above

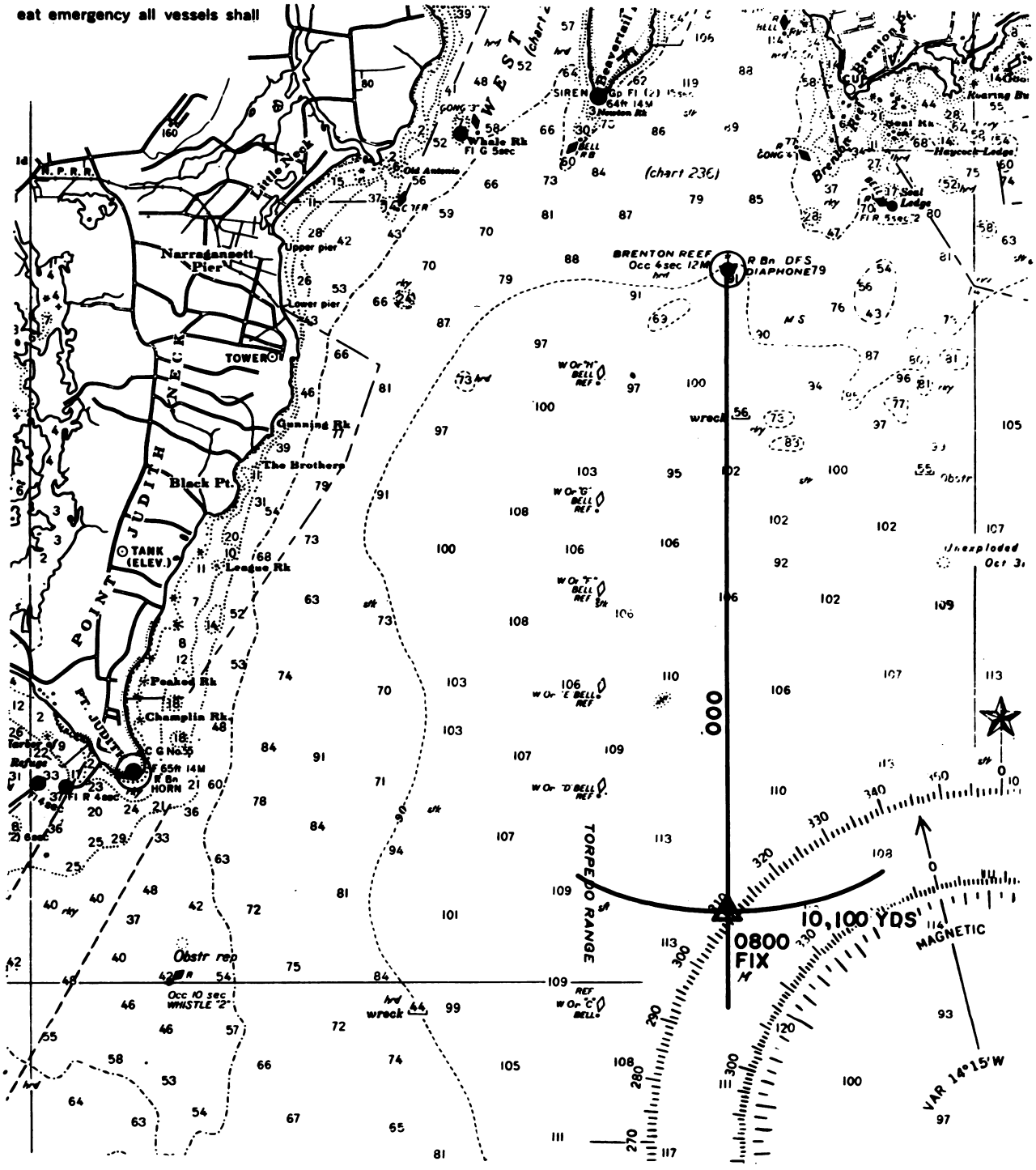

Figure 18-6.—Range and bearing to single object fix.

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mean high water, and is visible for 10 miles. "VISIBLE" means visible on a clear, dark night, at a height above the water of 15 feet.

Now that you know a little bit about measuring distances on a chart, about chart scales, and how to set the DRT to scale, and soundings, let us discuss the methods of obtaining radar fixes.

METHODS OF OBTAINING RADAR FIXES

The principal methods of establishing position by radar are as follows:

1. Range and bearing to a single object.
2. Two or more bearings.
3. Tangent bearings.
4. Two or more ranges.
5. Contour plotting.

Contour plotting is seldom if ever used in radar piloting and will not be discussed in this text.

The plotter should be able to select the best method for the particular circumstance. When possible, an alternate method should be used as a check. Whenever the accuracy of a position is in question, it should be designated an "estimated position," rather than a "fix," and treated with due caution. The symbol used for plotting an estimated position is ; a fix is plotted as a small triangle with a dot in the center, like this ; a dead reckoned position is indicated as ; a visual fix as . Time is indicated next to the symbol in the same manner as in all plotting.

RANGE AND BEARING TO SINGLE OBJECT

The type of radar fix most commonly used when operating close to shore is that obtained by a range and bearing on one object, preferably a small prominent target like a lighthouse, rock, or buoy.

For sake of accuracy, use of fire control radar is best for this method of plotting. The object to be used for the range and bearing should, if possible, be somewhere forward of the beam of the ship.

When the radar operator obtains the range and bearing he relays it to the plotter. With the parallel motion protractor the plotter aligns the rule on the correct bearing, then lays off the radar range to this target. The intersection of the bearing line and the range indicate your ship's position at that time. Figure 18-6 is a fix established by using a range and bearing to the same object.

One obvious advantage of this method is that it may be used when only one good object is available. The method is rapid, as the DRT operator can be provided with continuous ranges and bearings from the radar operator. Speed is especially helpful when approaching a turn or in restricted waters.

Even though this method is the most commonly used, it is not necessarily the most accurate. Therefore, one of the other methods discussed should be used along with it. There are many factors to be considered in the accuracy of this type of fix. Many of them you know about already, such as the beam width, the pulse width, and the calibration and tuning aspect of your radar.

TWO OR MORE BEARINGS

Cross bearings by radar (fig. 18-7) are plotted just as the navigator plots visual bearings. If the DRT plotter compensates for the beam width, the radar is in good bearing calibration, and the selected images of objects whose locations on the chart are accurately determined and are radar conspicuous, there is no reason why the resulting position should be inaccurate. This is especially true when a large number of bearings are used. Under some conditions, this method may be the most accurate available.

Notice in figure 18-7 that the radar operator took bearings on Pt. Judith (275°), a tower (320°), and Brenton Reef diaphone (000°). When possible, it is best to take bearings from aft of the ship to forward. The DRT operator, assuming no bearing correction is necessary in the example, uses the PMP to plot the bearing lines to these points on the chart. The point of intersection of the bearing lines is the position of own ship at that time.

When possible, the radar operator should take bearings on the exact center of the selected target. However, at times, he will have to take tangent bearings on the right or left edge of a body of land, as in the fix obtained in figure 18-8.

TANGENT BEARINGS

A bearing to the edge of a large object, such as an island, is known as a "tangent bearing." It is perhaps the least accurate method of all the methods discussed. However, it is often used

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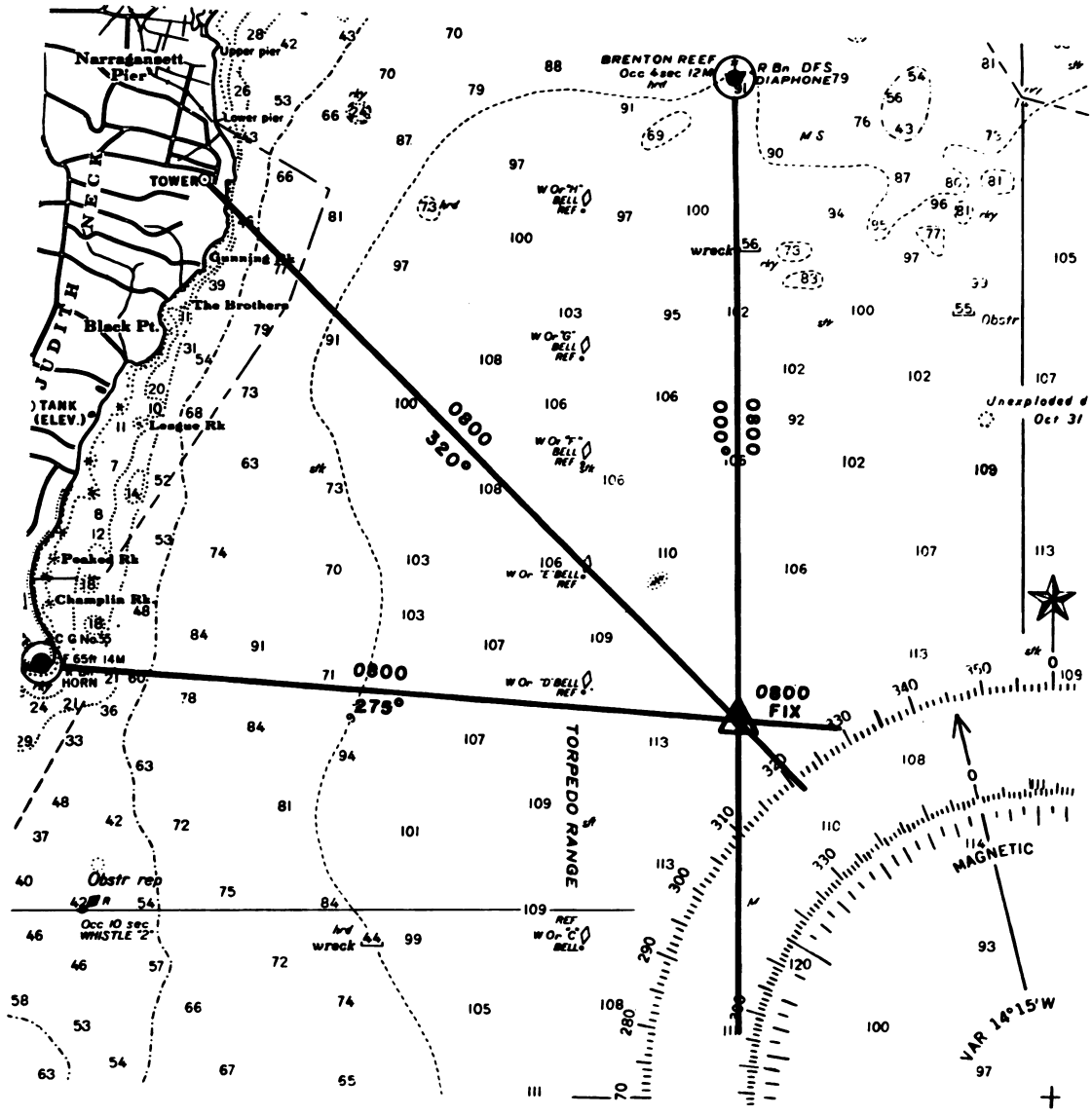

Figure 18-7.—Three bearing fix.

to supplement a range and bearing to a single object fix. Tangent bearings have all the possible sources of error of other bearings, plus the chance that an error might be caused by the true waterline of the object not showing on radar because of the curvature of the earth. Figure 18-8 shows how beam width distortion causes the tangent bearing lines to intersect at a range less than the measured range. Note that the fix is considered to be on the measured range, midway between the bearing lines. Right tangent bearings should be decreased by half the radar beam width, and left tangent bearings increased by the same amount. Remember, the fixes obtained by tangent bearings are less accurate than bearings on well-defined small objects.

TWO OR MORE RANGES

In most situations, the most accurate position will be determined by using two or more (preferably three) ranges, using bearings only to help identify the objects ranged on. Radars are usually more accurate in range than in bearing. There is no chance for mistakes caused by gyro error or beam width in the range method.

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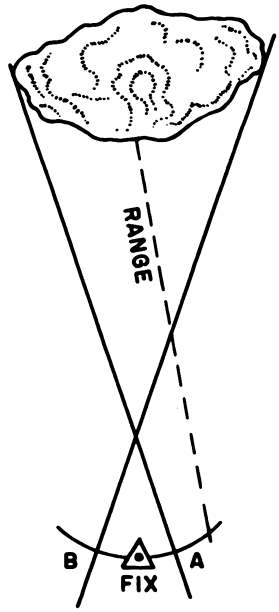

Figure 18-8.—Tangent bearing fix.

Furthermore, an error in range calibration is practically constant at all ranges, and can easily be compensated. Using the scale on the chart, the DRT plotter adjusts the radius of a drafting compass of 16-inch beam compass to match the range reported by the radar operator. As shown in figure 18-9, the plotter then swings an arc from the point to which the range was measured. The ship was at the intersection of several arcs at the time the ranges were taken. To reduce the error caused by the time lag between the time mark and the range measurements, the DRT plotter should make sure that the range changing most rapidly is measured first after the time mark.

The greatest opportunity for error in fixing a ship's position by radar ranges lies in the possibility of poor interpretation of the radar information displayed on the scope. Therefore, the skill with which the DRT plotter can determine the exact location on the chart of the radar information is the criterion of accurate fixes by this method. If arrangements are made for fire control radar to be "locked on" the small well-defined selected object, the accuracy of positions will be measurably increased.

HINTS IN SCOPE INTERPRETATION

Scope interpretation is a large subject that can best be mastered by experience, but here are some hints that will help you.

Small isolated rocks are excellent targets for center bearings and ranges. They are small, well-defined objects which can be plotted accurately from the exact point of echo. Small islands are as good, but large ones, as you have seen, require tangent rather than center bearings.

Sharp points of land are often used for ranges, and for either tangent or center bearings. In ranging on land, you must be certain to plot the range arc from the point which actually produced the radar echo. Sometimes what appears to be a water line on a radar scope is actually a reflection from some point inland, or possibly from a surf line offshore.

Buoys are good objects for ranges and bearings because, like small rocks, they are well-defined small targets producing sharp echoes. The chart symbol for a buoy is a diamond shape. Notice in the preceding illustration that near every buoy symbol there is a small dot. This dot represents the buoy's exact location. The diamond shape itself is not drawn to scale, and may be considerably off the buoy's actual position. Remember, however, that buoys may go off their stations for a number of reasons, so treat a fix obtained from buoys with caution until you are certain they are exactly in position.

Offshore lighthouses, rocks, or pilings are very reliable radar targets; they are also easy to identify on the chart.

Charted buildings, tanks, and towers, like the ones we used in our illustrations, often can be picked up by an experienced operator, even though they may be located some distance inland. The chart symbol of a tank and tower is a small circle with a dot in the center.

When distant mountains are the only objects available, you must remember that it is difficult to get an accurate range from such a large mass. Bearing inaccuracies must also be considered under such circumstances.

SET AND DRIFT

If you have ever rowed a boat across a river or stream with strong current, you know you have to point the boat in a direction different from that of the point where you desire to land. In other words, you have to apply a course and speed correction in order to get where you are going. You WOULD be experiencing "set" and "drift." "Set" is the direction toward which the forces of current tend to push the boat, and "drift" is the velocity in knots. Ships often experience the same difficulty as the boat just

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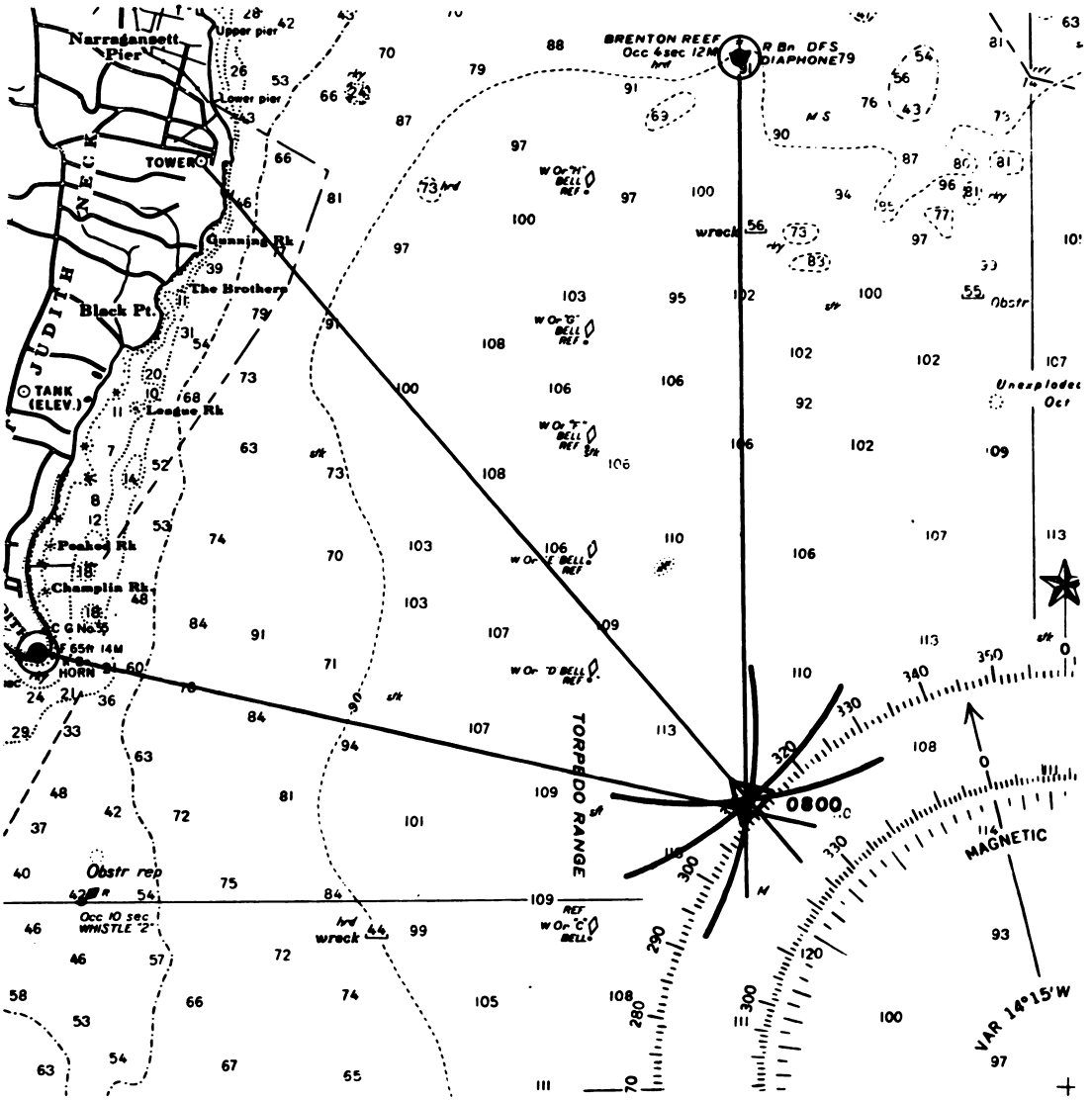

Figure 18-9.—Three range fix.

described. The navigator of a ship must allow for current in exactly the same manner. His problem will be:

1. To find the course and speed the ship will make good when steaming a given course at a given speed.
2. To find the course he must steer and a speed he must steam in order to have the ship make good a desired course and speed.

As you know, dead reckoning is the process of determining a ship's position by applying to the last well-determined position the run that has since been made, using only the true courses steered and the distance run as determined by pit log or engine revolutions, without considering current.

The discrepancy between the dead reckoning position and an accurate fix is the result of the action of various forces on the ship, plus errors in calculation of course and speed. Whatever the actual components which go to make up this discrepancy, it is always referred to as the effect of CURRENT, even though only a small part of it, possibly none at all, may be the result of actual ocean currents.

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The navigator will check through various publications, tide tables, current tables, and the like to predict the amount of set and drift the ship will experience while entering port. However, winds, variations in stream discharges produced by heavy rain, and other weather factors frequently have an effect upon direction and velocity of current. When such is the case, actual current conditions will naturally vary from those predicted. Thus, it becomes necessary for both the navigator and the CIC to periodically determine set and drift, especially in restricted waters. CIC also sends set and drift to gunnery personnel during shore bombardment to be set in their computers as target course and speed.

Suppose your ship is entering port and the navigator has laid down a proposed track of 200° and he desires to maintain a speed of 12 knots. Your first job would be to determine the set and drift for comparison with the navigator's solution. If the ship has moved off the track you would recommend a course and speed to get back on the track as well as a course to make good 200° speed at 12 knots. Let us see how this can be done.

HOW TO DETERMINE SET AND DRIFT

The method CIC uses to determine the direction and the amount of drift is as follows: Follow the discussion by referring to figure 18-10.

1. Obtain an accurate fix. Shown as time 1405 in the illustration.
2. Dead reckon the ship ahead 3 minutes on the course indicated by gyro compass, at the speed indicated by pit log, from the 1405 fix. Be sure to use the scale given on the chart. The ship is on course 200°, speed 12. Thus, using the 3-minute rule:

$$\text{Speed} = \frac{\text{Distance traveled in 3 minutes}}{100}$$

   the answer is 1200 yards, or 400 yards per minute.
3. At time 1408, or 3 minutes later, obtain another accurate fix.
4. Set is the bearing of the fix from the DR to the fix. Align the PMP ruler along a line from the DR to fix, and read bearing. In the illustration, we get a bearing of 080°. The ship is being set off course in the direction of 080°.
5. Drift is the velocity in knots that the ship is being pushed in the direction of 080°.

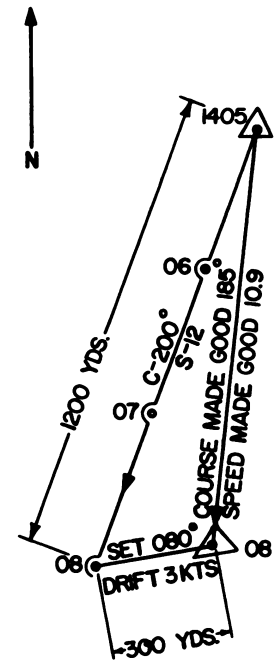

Figure 18-10.—Determining set and drift.

While the PMP is aligned along the direction from the 08 DR position to the 08 fix, measure the distance between these two. Notice we get a distance of 300 yards. Using the 3-minute rule again, divide 300 by 100. The drift is 3 knots.

6. As a result of the set and drift, the ship is actually moving in a direction of 185° at a speed of approximately 10.9 knots instead of 200° speed 12.

If you have the DRT set up to the scale of the chart and use the "bug" to keep track of own ship's movements on the chart, you can determine the set and drift from the position of the "bug". Here is how to do it. First, obtain a fix and hurriedly position the "bug" exactly at this position. After 3 minutes take another fix and at the same time mark the "bug." The set is the bearing from the "bug" to the fix. The drift is determined in the same manner as explained.

TO DETERMINE HEADING AND/OR SPEED TO RETURN TO A DESIRED TRACK

To determine the correct heading and speed to return to a desired track, first compute the set and drift (fig. 18-11). Then plot the current vector from the DR position at the time for which you wish to solve the problem. From the head

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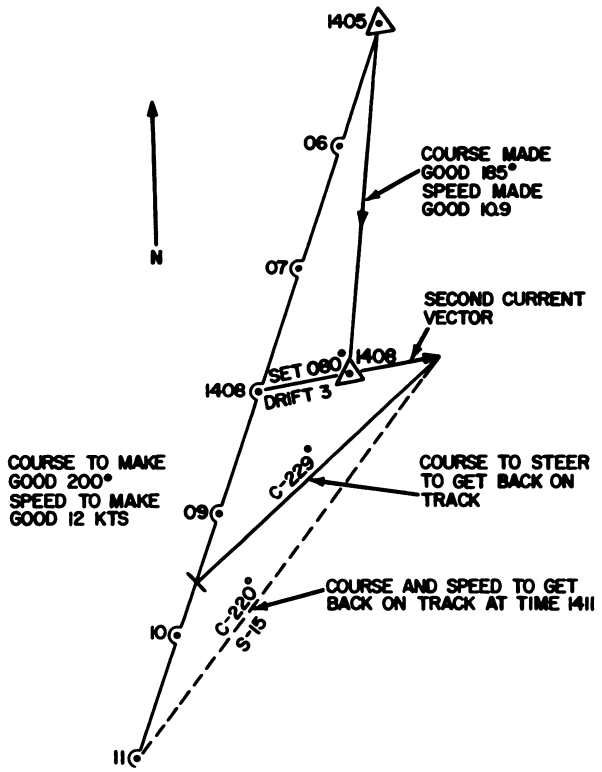

Figure 18-11.—Determining heading and/or speed to return to desired track.

of this vector, plot a second current vector, and from the head of the second vector, with a radius equal to the ship's speed, strike an arc on the desired track. The direction of the line joining the head of the second current vector to the desired track is the course to steer. The time taken will be the time you have used to obtain the length of the current and speed vectors and may be varied to suit particular circumstances. Notice in figure 18-11 that at time 1405 we obtained an accurate fix. At time 1408 the set (080°) and drift (3 knots) were computed. We find that the ship is 300 yards off the proposed track. We want to get back on track. From the 1408 fix we drew a second current vector in the direction of the set and length of the drift. From the 1405 fix to the 1408 fix we found the ship's speed to be 10.9 knots. With a compass we measured off 10.9 knots and from the head of the second current vector we struck an arc across the proposed track. The direction from the head of the second current vector to the point where the arc crosses the track indicates the course to steer to get back on the track.

By inspecting the plot, you can see from the proposed DR on the track that you are going to be behind in time. To determine the course and speed to recommend to the navigator for returning to the track by a given time in order to make good a given speed, first, draw a vector from the head of the second vector to the time desired to be back on track. This line is represented by a dotted line in the illustration. The length and direction of this line indicates the course to steer and the speed to make.

Now that you are back on the proposed track, you will drift off again unless you correct for the set and drift.

TO DETERMINE HEADING TO MAKE GOOD A GIVEN COURSE

To determine the correct ship's heading to make good a given course, begin by finding the set and drift as described. From a fix, lay out both the course to be made good and the set and drift vector. See figure 18-12. From the head of the set and drift vector, swing an arc the length equal to the speed of the ship through the water. In our example we get a speed of 10.9 knots. The direction of a line drawn from the head of the current vector to the point where the speed arc intersects the desired course is the heading to use.

TO DETERMINE HEADING AND SPEED TO MAKE GOOD A GIVEN COURSE AND SPEED

To determine the correct heading and speed to make good a given course and speed, it is necessary first to compute the set and drift. Now, from a fix, draw both the course and speed vector to be made good and the set and drift vector. See figure 18-13. The direction and length of a line drawn from the head of the current vector to the head of the given course and speed vector provide the heading and speed to use.

Even though the set and drift problems were presented in a step by step procedure it does not necessarily follow that manner. Most of the time you will work all solutions as soon as you find there is a set and drift and then make your recommendations all at once.

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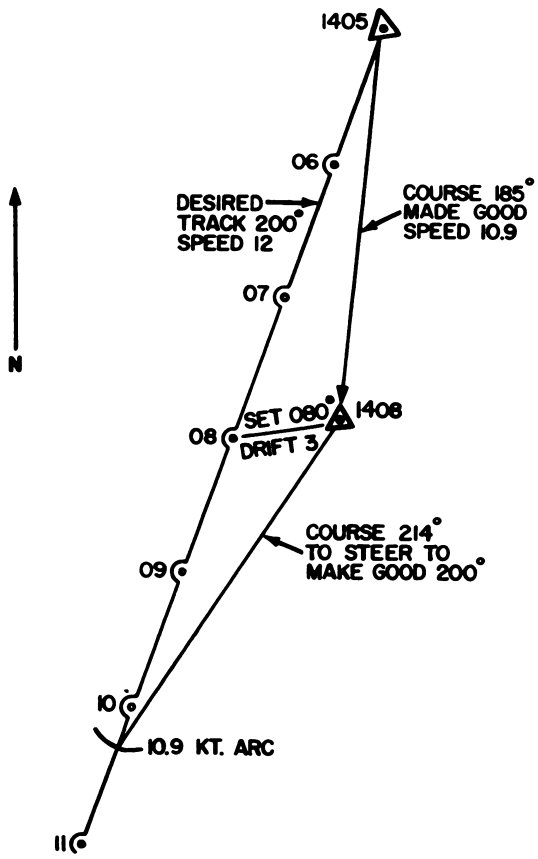

Figure 18-12.—Determining heading to make good a given course.

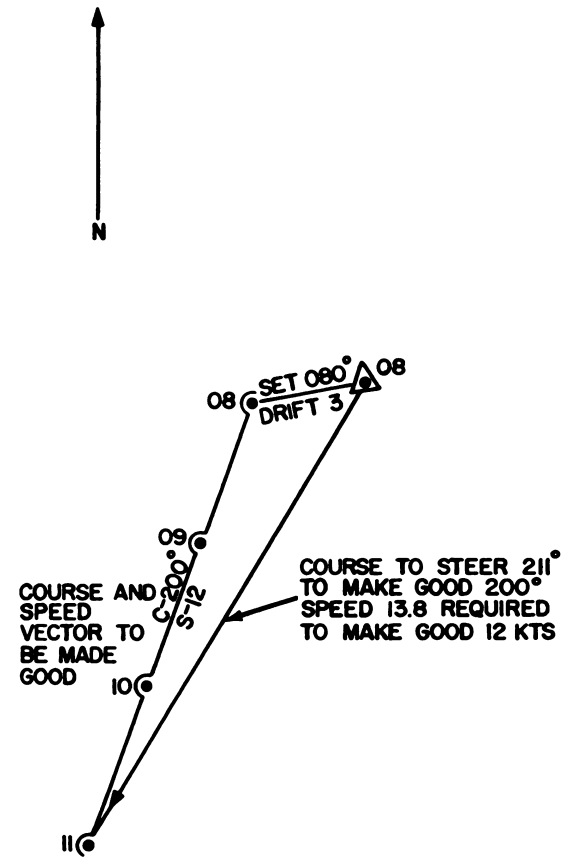

Figure 18-13.—Determining heading and speed to make good a given course and speed.

QUIZ

1. What are the four ways of determining position in navigation?
2. What are the imaginary lines running through the poles and around the earth?
3. How many degrees of latitude are there between the equator and the North Pole?
4. Where do you find a chart whose consecutive number is A5300A?
5. In an index catalog, how do you find what portfolio contains the chart of a specific area?
6. What is the primary medium for distribution of corrections to charts, light lists, and other hydrographic publications? How often is it issued?
7. What is the purpose of the chart correction cards (From H.H.O. 1278).
8. Are charts ordered by chart or by consecutive number?
9. In addition to adjusting the DRT vernier to the chart scale, what other equipment has to be made to conform to the same scale?
10. How many general methods are there of obtaining the ship's position by radar? Name them.
11. What is the symbol for a radar fix? A DR position? A visual fix?
12. What is meant by set and drift?

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APPENDIX I

ANSWERS TO QUIZZES

Chapter 1

THE RADARMAN

1. Starts as an operator of radar equipment and as a plotter and status board keeper.
2. A heading under which are grouped jobs requiring about the same skills, knowledge, and training.
3. Rates are steps for advancement, or pay grades, within each rating.
4. Twelve. Group I, called the deck group.
5. A Radarman can be assigned to any Navy ship.
6. Manual of Qualifications for Advancement in Rating.
7. Published in the Quals Manual, near the front, preceding the professional qualifications for the various ratings.
8. Two, practical factors and examination subjects.
9. A special checkoff sheet which lists the practical factors for the rate to which you are advancing.
10. The reading list for Radarmen contained in NavPers 10052.
11. The instructions at the front, the page with the sources you should study to meet the military requirements for advancement, and the page listing the sources to study to qualify professionally as a Radarman.
12. This book is a self-study course written to help you become a Radarman with the least possible outside assistance.

Chapter 2

RADAR NOMENCLATURE

1. Nomenclature designations are used primarily as the short titles to equipments.
2. Before the merger of the services, the nomenclature system was called the joint Army-Navy nomenclature system.
3. The system is applicable to all radio, radar, and sonar equipments, and, once learned, facilitates the recognition and identification of all Navy equipments.
4. The coulomb is used as a unit for measuring the quantity of electrical charge.
5. The British scientist, Fleming, pointed out that an electric current is a drift of free electrons through a conductor.
6. If 6.28×10^{18} electrons flow past a given point in 1 second, we call this amount 1 ampere of electrical current. Therefore, the unit of electric current is the ampere.
7. In an electrical formula, the capital letter R stands for resistance.
8. The volt is the electromotive force (EMF) necessary to cause 1 ampere of current to flow through a conductor which has a resistance of 1 ohm.
9. The unit of electrical power is the watt.
10. A cycle is one complete series of events at the end of which conditions are as they were at the starting point.
11. Radio energy can travel a certain distance in a given time. This distance is called wavelength.
12. Radar energy travels at a velocity of 162,000 nautical miles per second.
13. Expressed in megacycles, 300,000,000 cycles is written as 300 MC.

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Chapter 3

RADAR OPERATION AND METHODS

1. It is 1100 feet distant.
2. Direction, distance, and height.
3. Speed is 300,000,000 meters per second.
4. Creating an electron beam, controlling its intensity, and focusing it on the screen.
5. To prevent oxidation of the cathode and heating element and to permit the flow of current from cathode to plate without colliding with gas particles.
6. Accelerating and focusing the electron beam.
7. The control labeled INTENSITY.
8. By changing the voltage on the grid.
9. Deflection plates.
10. Continuous wave (CW).
11. Pulse radar does not depend on the relative frequency of the returned signal or on the motion of the target.
12. Collect, display, evaluate, disseminate, and control and assist.
13. The OI division.

Chapter 4

USES OF RADAR

1. Surface-search, air-search, low-angle search and height-finding radars, and IFF.
2. Detecting targets and hazards on the surface.
3. Fire control radars are capable of a high degree of accuracy since they have extremely high frequencies, high pulse repetition rate, short pulse width, and narrow beam width.
4. Detection, identification, evaluation, passing collected information to gunnery, and assisting fire control radars to acquire the target and scan firing areas to ensure protection of friendly units.
5. Personnel at gunnery control and gun director stations should know the type and extent of information from CIC, methods obtained, and how disseminated.
6. Presence, range, bearing, nature, number, size, and altitude.
7. Interpretation of radarscope picture and passing information to those who need to know.
8. Sometimes detection can be made by visual means only.
9. Detection and ranging.
10. The transmitter pulse, because the duplexer allows some of the transmitted pulse power to reach the receiver.
11. PPI.
12. As a bright spot at a distance from the center of scope proportional to the range of the target.
13. Indicate altitude of a radar contact.
14. Horizontally.
15. Approximately 6.1 microseconds.
16. As a reference in estimating ranges when speed is essential.
17. By use of a range ring or range strobe.
18. Rotate the cursor until it bisects the target and read bearing circle or bearing counters if available.
19. The altitude is equal to the slant range multiplied by the sine of the angle of elevation.

Chapter 5

FUNCTIONAL COMPONENTS

1. The higher the carrier frequency, the smaller the antenna array.
2. The persistence of the screen and the rotational speed of the antenna.
3. The width of the transmitted pulse (receiver is blocked during transmitter pulsing periods).
4. It produces the synchronizing signals that trigger the transmitter, trigger the indicator sweep, and coordinate the other associated circuits.
5. To generate R-F energy in short powerful pulses.
6. Because of the relatively long resting time between pulses.
7. Repetition rate oscillator, overdriven amplifier, cathode follower, differentiating circuit, and blocking oscillator.
8. (a) A moving electric field creates a magnetic field;
   (b) a moving magnetic field creates an electric field.

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9. Antenna reflector unit, duplexer or reprod, and transmission lines.
10. The duplexer.
11. The power from the transmitter would destroy the receiver.
12. The coaxial cable.
13. Reflecting dipoles are placed the correct distance behind the radiating dipoles.
14. They are small lobes produced by array antennas beside the larger or major lobe.
15. Superheterodyne.
16. Because no means has yet been found to amplify microwave signals.
17. To the radar (indicator) through a video amplifier.
18. The grid becomes more positive with respect to the cathode and more electrons enter the cathode ray beam and the picture becomes brighter.
19. The video amplifier signal voltages can be applied to the CRT grid to modulate the intensity of the beam.
20. A pair of electromagnets.

Chapter 6

SURVEILLANCE RADARS

1. To provide a means for transmitting the radar information to various remote display points from each radar.
2. IFF or Mk 10.
3. Information normally is incorporated into the distribution system.
4. The SG-6 has two antennas, one for surface search and one for zenith search (the latter called a clamshell type of antenna), whereas the SG-1B has a parabolic type of antenna.
5. The AN/SPS-4 is similar to the SG-6B except for changes in the antenna, the transmitter, and the receiver to permit operation on the lower frequencies and at a higher power output.
6. AN/SPS-21, AN/SPS-35, and AN/SPS-36.
7. Surface craft radar for navigational purposes.
8. It had a tiltable antenna that could be elevated to detect aircraft at short ranges.
9. The square root of 81 is 9; 9 times 1.22 equals 10.98; therefore the radar horizon of an 81-foot high antenna is approximately 11 miles.
10. This R-F line filter serves to eliminate R-F leakage (conducted noise) from the primary source to the radar set and from the radar set to the primary power source.
11. In the receiver-transmitter.
12. The echo box can be tuned by means of a pushbutton on the radar set control which operates the control motor of the echo box, or by means of a manual tuning knob attached to the shaft of the echo box.
13. Radar set control.
14. General control unit.
15. Automatic frequency control (AFC) circuits.
16. The sensitivity time control (STC) circuit.
17. The STC circuit is of value in reducing sea return saturation at close ranges so that nearby targets can be distinguished.
18. The fast time constant (FTC) circuit.
19. Synchro signal amplifier.
20. The AN/SPS-12 is similar to the AN/SPS-6 but includes a more sensitive receiver, a separate modulator, and a larger antenna.
21. Fire control.
22. Maximum range of 100,000 yards.
23. Low angle search and height finding.
24. The BPS-2 is a submarine air-search radar installed in SSR's.
25. The square root of 10,000 feet (100) times 1.22 equals approximately 122 miles.
26. Range should be 100 times 1.22 plus 9 equals 131 miles.
27. The scope "blanks out" and there is no transmitted pulse.
28. Only when the order is given by the CIC.
29. Reduce all gain and intensity controls fully counterclockwise.
30. (a) It will detune the receiver.
    (b) The pip loses its shape and becomes ragged and decreases in size.
31. (a) To enable you to obtain an accurate performance check on the radar.
    (b) By observing the initial range at which you are able to detect targets.
32. At the beginning of each watch and as often thereafter as you deem necessary.
33. Set receiver gain as you would for short-range search.
34. To any position, free of targets, out to several thousand yards. To keep echoes from appearing in the ring time.
35. It drives the echo box echo, or ring time, to saturation.
36. Several readings must be taken and then averaged and recorded.
37. A loss of 150 to 250 yards is considered significant.
38. Voltage standing wave ratio must not exceed 1.5 to 1.0.

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Chapter 7

PLAN POSITION INDICATORS

1. The remote repeater is a smaller, lighter, general-purpose unit capable of accepting inputs from more than one type of radar, allowing it to be used for more than one function.
2. Video, antenna synchro, and trigger.
3. Centralized distribution system.
4. Standard, projection, large diameter, delayed, and range-height indicator.
5. It is necessary so that the azimuth or bearing at the remote indicator will agree with the correct bearing as observed at the indicator of the radar.
6. This is to prevent a "surge" of voltage in the cathode ray tube which might damage its viewing screen.
7. The "B" presentation.
8. Poor pip definition.
9. Delayed PPI.
10. Off-centering.
11. Since CIC is a dark space, you cannot see the controls, and knowing their location and function will eliminate the need for matches, cigarette lighters, flashlights, and so forth.
12. Don't crank range too low to hit stops nor too high and stand a chance of ruining the gear.
13. Range-height indicator scope.
14. Section 4 of the instruction book for the individual equipment.

Chapter 8

OPERATIONAL TECHNIQUES

1. Through proper procedure and teamwork.
2. Make sure the radar is tuned and properly adjusted for searching. Find out the tactical situation so that you may search more effectively in the probable direction of attack.
3. A search operator who has to divide his attention between searching for new targets and tracking previously detected contacts is operating near saturation level.
4. The radar control officer (when assigned), or the CIC watch officer. The CIC watch officer may delegate this authority to the leading Radarman in CIC.
5. Try own ship's CIC doctrine. Then try NWP 31 and the NWIP 31 series.
6. The long pulse will increase the radar detection, but will reduce the range accuracy and range resolution. The short pulse improves accuracy and range resolution at a sacrifice in detection performance.
7. To prevent burning of the screen in the cathode ray tube.
8. The centering controls.
9. It must be borne in mind that all special circuits reduce signal return to some extent; therefore, they should be used only when necessary.
10. (a) PPI and A-scope at main console set on 200 miles.
    (b) Pulse length in NLP; gain control adjusted for approximately 1/4-inch grass.
    (c) Focus control adjusted for thin trace at range of expected contact.
    (d) Receiver tune control adjusted for maximum reception.
    (e) AFC on.
    (f) STC, FTC, and IAVC off.
    (g) Slowest automatic antenna rotation with occasional manual sweep.
    (h) Watch the A-scope with alternate inspection of PPI.
    (i) Find out tactical situation (where to search).
    (j) Pay particular attention to the outer portion of the scope.
11. (a) The evaluator.
    (b) From information from plotters and radar operators.
12. The E-unit system is standard in the Navy and is a convenient system to use. By providing common terms with which to discuss the strength of echoes, it reduces confusion and misunderstanding.
13. No. There may be times when the IFF of a friendly craft or your IFF is inoperative. All contacts are treated as "enemy" until positively identified, however.
14. The pip from the airplane will bob violently.
15. (a) That another target does not sneak in.
    (b) An occasional 360° rotation.
16. Report everything. You will be told to continue reporting and when to cease reporting or to just watch the contact.

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Chapter 9
FACTORS AFFECTING RADAR

1. The maintenance factor.
2. The maximum measurable range of a radar is determined by the PRR. MRR equals 82,000 divided by the PRR.
3. Conducting materials.
4. The more slowly the antenna rotates, the greater the detection range of the radar.
5. The pulse width.
6. Range scale, calibration, alignment of markers, frequency drift, fixed error, and how well the operator aligns the range ring or strobe with the pip.
7. Range resolution is the ability of a radar to resolve between two targets at the same range but with different bearings.
8. The antenna's horizontal beam width.
9. It would produce a pip about 15° wide.
10. Receiver gain control.
11. If possible, compare the altitude of friendly planes with that of bogies.
12. (a) The composition of the atmosphere which controls the amount of bending that the waves experience in their passage;
    (b) the diffraction that bends the waves over the horizon to some extent;
    (c) the reflection of the radar waves from the surface of the sea. Other factors are antenna pattern, attenuation of waves, and the size and character of the target.
13. A serious operational consequence of trapping is that it misleads radar operators regarding the over-all performance of the equipment. Long-range echoes caused by trapping have frequently been assumed to indicate good condition of the equipment when precisely the opposite may be the case.
14. No. It depends on the altitude of the duct.

Chapter 10
PIPOLOGY

1. Echo interpretation means finding out how many targets are visible on the radar screen, how fast they are going, in what direction, bearing, range, and altitude. Composition is the term used in the analysis of pips to designate how many targets, type, and if possible identification of targets.
2. Four characteristics of pips useful in interpretation are: (1) size, (2) shape, (3) fluctuation in height, and (4) movement.
3. The relative size of various targets at the same range.
4. When the beam of energy can strike the hull of a ship. Relative bearing from the target.
5. Fluctuation shows, by its speed, whether the target is large or small; rapid fluctuation, small target; slow fluctuation, large target. Aircraft carrier will not travel at 100 knots and an airplane seldom does less.
6. It is an area in which no resolution is possible.
7. Count the pips and multiply by three.
8. The apparent movement is due to motion of own ship and to the effect of the slope of the shoreline.
9. An aircraft carrier will not travel at 100 knots and an airplane seldom does.
10. Pips that appear to be given off by planes or ships, but are not. Sea return, clouds and minor lobes.
11. The portion of land behind hills, and the like, which cannot be detected. Beam width distortion causes widening of the target. Pulse length distortion causes increased target depth.
12. The combination of beam width distortion and side and back lobes.
13. A change of course by the target.
14. Usually the antenna is not mounted high enough and the beam strikes the mast or superstructure of own ship.

Chapter 11
MAINTENANCE AND SAFETY

1. The two general categories of ratings responsible for proper performance of electronic equipment are operators and technicians.
2. The radar operator responsibilities toward his equipment come under the heading of operational use, manipulation, operational maintenance, and preventive maintenance.

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3. Tags serve as a warning so that no one will turn the power back on while you are working on the gear.

4. Prior to touching a capacitor, always short circuit the terminals with the shorting bar.

5. The recommended method for cleaning the chassis and cabinets of equipment is to use a soft brush having no metallic parts, along with the vacuum cleaner, to loosen dust for easier removal by the vacuum cleaner.

6. Solvents are harmful to electronic equipment. They dissolve waxes and compounds that protect equipment from fungus growth. They soften most types of insulation and cause it to become saturated with dirt, tar, or oil.

7. It is important that air filters be vacuumed frequently in order to prevent equipment from overheating and causing great damage. In addition, when a filter becomes excessively dirty, a lot of time and work are required to clean it.
8. Meters in an electric circuit measure current, voltage, and resistance.
9. In section 4 of the equipment instruction book you will find detailed instructions for turning on the equipment, securing it, tuning procedures, and checks to be made while operating.
10. A good reference for operator maintenance of a specific equipment is section 5 of the instruction book.
11. The Navy has set up a POMSEE program which, when followed closely, will keep equipment at peak performance and cut down the number of failures.

Chapter 12

TELEPHONE AND TALKING PROCEDURES

1. Every member of the CIC team must be an expert in voice communications.
2. By use of reliable communication channels and standard procedure which enable us to pass information instantly and properly to all who need the information.
3. Sound-powered telephones.
4. Use of the MC system greatly increases the noise level in CIC. The system is robbed of its value as an alarm to attract attention if other than urgent information is passed over it.
5. The master console combines radiophone, interphone, intercom, sound-powered telephone, and 20MC announcing circuits in one master console station.
6. Sound waves.
7. Before inserting plug into its jack box.
8. Remove one of the earphones from the headband and use it as a transmitter by speaking into it.
9. Moisture, dust, and dirt can soon cause a short circuit in a jack box that has been left uncovered.
10. The I. C. Electricians.
11. He must be able to speak well (clearly, loudly), listen well, and remember a series of words and numbers so that they can be repeated exactly.
12. The JA.
13. The XJA.
14. The basic form for transmitting a message by sound-powered telephone consists of the standard shipboard names for the station called and the station calling, followed by the text.
15. I have received all of your last transmission.
16. ACP 165.
17. By using a standardized system and following the rules that apply to the pronunciation and expression of numerals.
18. Always digit by digit, and preceded by the word Time.
19. They are spelled out, using the phonetic alphabet.
20. What it is, where it is (bearing and range), time of observation.
21. By the phonetic alphabet preceded by Skunk if identity is unknown.
22. The word Raid, followed by a numerical designation such as 1, 2, 3, etc.

Chapter 13

LOGS, RECORDS, REPORTS, AND PUBLICATIONS

1. Personnel, equipment, operation.
2. To provide a complete and accurate performance and operation record for evaluation, writing reports, and positive proof that certain things were done or that certain events occurred at a certain time.
3. The CIC officer.
4. CIC watch log, radiotelephone logs (maneuvering net, task unit or group or force chain of command net, combat information net), radar performance log, radar navigation log, radar countermeasures log.

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5. You will evaluate and assign grades on the junior petty officers and nonrated men under your supervision to be reviewed by your division officer.
6. (a) Record of Practical Factors;
   (b) two;
   (c) military requirements for enlisted personnel and professional requirements for Radarmen;
   (d) at the top of the front page of the form.
7. Naval Warfare Information Publications (NWIP) give detailed technical instructions to supplement the doctrine found in the NWP's.
8. ATP-1
9. The operator or technician who detected the failure.
10. Chapter 6 of FXP 3.

Chapter 14
SURFACE PLOTTING

1. The CI net talker makes his first report on an air contact to the air raid reporting control ship, if in use. If not, he reports to air defense ship or OTC.
2. A relative bearing is a bearing taken in reference to own ship's head, which is 000°R. Relative bearings progress clockwise through 360°R.
3. A bearing written 150° would be a true bearing unless stated otherwise.
4. The geographic or true plot is kept on the DRT.
5. In timing plots, four digits are used on the initial plot and on the start of a new hour.
6. Surface summary plots on large ships are usually located in COTP and flag plot.
7. Ships maintain station in a formation by using a designated guide for range and bearing reference.
8. A surface contact is reported to the OOD as soon as detected.
9. Surface contacts are reported on the CI net at least every 3 minutes or when a change of course or speed is noted.
10. IFF code assignments are placed on the electronic status board.

Chapter 15
AIR PLOTTING

1. The objective of air plotting is to present a neat, accurate, up-to-the-minute picture of the position and track of all aircraft in the area under surveillance.
2. Although the summary plot is primarily a picture of the air situation, surface forces which relate to the air picture are shown. Also reference points, dangers to air navigation, wind direction and velocity, position of sun, positions of outlying picket forces and raid designations are presented on the summary plot.
3. The x or > are the symbols that respectively represent unidentified and enemy aircraft.
4. EPAs provide an up to the minute track, despite a lack of radar information.
5. Split raids are given a letter designation preceded by the original number of that particular raid.
6. Because the true heading must be converted to magnetic heading for the pilot, as he does not have a gyrocompass.
7. The plotter must add easterly variation to and subtract westerly variation from magnetic heading ordered by aircraft controllers orders so that true heading can be obtained.
8. The OTC specifies the method of reporting raids and normally the method to be applied is set forth in the operation order.
9. The purpose of a reference point in conversion plotting is to enable all concerned to locate a contact reported by someone whose position they do not know.
10. The simplest and quickest technique for conversion is the parallelogram or eye method.

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Chapter 16
MANEUVERING BOARD

1. No; relative motion occurs only when the actual motion of two or more units is not the same.
2. The relative plot and the vector diagram.
3. It remains fixed.
4. At the center.
5. Direction of relative movement of the maneuvering ship with respect to the reference ship, and (by its length) the distance of relative movement.
6. When the directions of relative and actual motion happen to coincide.
7. The e-r vector, the e-m vector, and the r-m vector. e-r: actual course and speed of reference ship. e-m: actual course and speed of maneuvering ship. r-m: direction of relative movement and relative speed of maneuvering ship.
8. Courses and speeds.
9. (a) 228°.
   (b) 28.2 knots.
   (c) Astern.
   (d) 20,400 yards.
   (e) 17 minutes or time 0143.
   (f) 120°.
   (g) 16,500 yards.
   (h) 082°.
   (i) 142°.
   (j) In 3.5 minutes or time 0129.5.
10. (a) 221°.
    (b) 17 knots.
    (c) 025°. (R).
    (d) Ahead.
    (e) 249°.
    (f) In 17.5 minutes or time 1026.5.
    (g) 6600 yards.
11. (a) 293°.
    (b) 24.5 knots.
    (c) 28,700 yards.
    (d) 12 knots.
    (e) In 35 minutes or time 0535.
    (f) Astern.
    (g) 12,300 yards.
    (h) 140°.
    (i) In 26 minutes or time 0526.
    (j) 320°.
    (k) 5600 yards, 023°.
    (l) In 13 minutes or time 0513.
    (m) 243.
12. (a) 322°.
    (b) 28,000 yards.
    (c) 21 knots.
    (d) 053°, 9 knots.
    (e) Neither.
    (f) 210°.
    (g) 10,200 yards.
    (h) In 20 minutes.
    (i) 337.

Chapter 17
DEAD RECKONING EQUIPMENT

1. The two sources of course and speed information fed through the analyzer into the DRT are the ship's gyro and pit log.
2. Three types of controls in the DRT are: The electrical controls, the mechanical scale setting controls, and the "bug" positioning controls.
3. The 200-yard-per-inch scale is usually used for man overboard.
4. Time is indicated alongside your own ship's track by placing the hour and the minutes in a four-digit number next to the first plot and two-digit numbers indicating minutes, until the next hour.
5. The two methods of plotting ranges and bearings on the DRT are called direct and indirect plotting.
6. The surface recorder board serves to keep the evaluator informed, and is backstop for the plotters.
7. (a) 600 yds. in 1 minute equals 18 knots.
   (b) 1000 yds. in 2 minutes equals 15 knots.
   (c) 900 yds. in 3 minutes equals 9 knots.
8. A contact's designation is identified on the DRT plot by placing the letter designator in a large circle near the origin of the series of plots it identifies.
9. In case of a pit log failure the DRT can still be used by DR-ing the "bug" at speeds received from the bridge.
10. In case of a DRT failure DR your own ship not more than 8 to 10 minutes ahead.

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Chapter 18
NAVIGATION

1. The four ways of determining position in navigation are: Piloting, dead reckoning, celestial navigation, and electronic navigation.
2. The imaginary lines running through the poles and around the earth are called meridians.
3. There are 90 degrees of latitude between the equator and the North Pole.
4. The chart whose consecutive number is A5300A is the second chart (after A5300) in portfolio No. 53.
5. Find the portfolio number of the chart of that area in the Index Chart Of Portfolios.
6. The medium for distribution of corrections to charts, light lists, and other hydrographic publications is Notice to Mariners. They are published weekly.
7. The chart correction cards is a record of corrections.
8. Charts are ordered by chart number.
9. In addition to adjusting the DRT vernier to the chart scale, the plotting arm on the PMP has to conform to the scale.
10. There are six principal methods of obtaining the ship's position by radar. They are:
    1. Range and bearing to a single object.
    2. Two or more bearings.
    3. Tangent bearings.
    4. Two or more ranges.
    5. Contour plotting.
    6. The Virtual PPI Reflectoscope (VPR).
11. The symbol for a radar fix is a triangle with a dot in the center. A DR fix is a half of a circle with a dot in the center. A visual fix is a circle with a dot in the center.
12. Set and drift is the effect of the wind and current on the movements of a ship.

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APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

RADARMEN (RD)

Quals Current Through Change 15

General Service Rating

Scope

Radarmen perform basic and control functions of CIC as plotters, operators, status-board keepers, and talkers; maintain CIC displays and advise on capabilities, limitations, and condition of assigned equipment. Radarmen apply a thorough knowledge of CIC doctrine and procedures contained in NWP and NWIP publications; tactical doctrine and procedures contained in ATP, NWP, and NWIP publications; operational communications doctrine and procedures contained in ATP, ACP, JANAP, DNC, NWP, and NWIP publications; and hydrographic procedures necessary for radar navigation contained in Hydrographic Office publications.

Radarmen operate, perform operational and preventive maintenance on, and locate common circuit failures in surveillance and altitude-determining radars, IFF equipment, electronic countermeasures equipment to which assigned, radiotelephone equipment, and associated equipment.

Emergency Service Rating

Same as General Service Rating.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see Manual of Navy Enlisted Classifications, NavPers 15105-A, codes RD-0300 to RD-0399.

Qualifications for Advancement in Rating	Applicable Rate
	RD
100 PRACTICAL FACTORS	
101 OPERATIONAL	
1. Start, stop, operate, and tune surveillance and height-finding radar equipment, including associated IFF and target designation equipment, to which assigned	3
2. Start, stop, operate, and adjust remote plan position indicators (RPPI) to which assigned	3

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Qualifications for Advancement in Rating	Applicable Rate
	RD
101 OPERATIONAL—Continued	
3. Adjust parallel motion protractor equipment, position bug, and make appropriate scale and quadrant setting on dead-reckoning tracer (DRT)	3
4. Start, stop, and operate transmitter remote control units used for radiotelephone	3
5. Distinguish between radar contacts caused by ships, aircraft, and missiles and those caused by natural disturbances	3
6. Determine the following contact information from appropriate radar equipment: Range, bearing, altitude, composition (estimate), and identification (IFF)	3
7. Maintain at least three tracks on geographic, summary, and surface plots, including dead reckoning of air and surface targets	3
8. Solve maneuvering board problems for course and speed, closest point of approach of contact, and maneuvering to new position	3
9. Maintain all types of status boards found in CIC	3
10. Plot ranges, bearings, and fixes on nautical charts, including dead reckoning	3
11. Set up formations and screens on surface plot by direct reference to current tactical publications	3
12. Convert given positions into grid coordinates	3
13. Transmit, receive, and authenticate on CIC radiotelephone circuits, using standard vocabularies, procedures, and techniques	3
14. Serve as S/P telephone talker in CIC, using standard procedures	3
15. Measure radar ringtime	3
16. Start, stop, operate, and tune electronic countermeasures equipment to which assigned	2
17. Classify intercepted electromagnetic radiations such as: Radar and/or IFF signals, jamming signals, guided missile control signals, communication signals (teletype, CW, television), and navigational aids signals	2
18. Determine the following information from an intercepted electromagnetic radiation signal: Frequency or frequency range, presence of frequency shifting; antenna polarization, antenna beam width, antenna scan rate, presence of lobe switching, pulse width, pulse repetition rate, and bearing	2
19. Perform the basic functions of CIC by furnishing information regarding location, identity, and movement of contacts, determined by interpreting information gained from radar and electronic countermeasures equipment and data derived from plots maintained	2
20. Perform CIC duties related to navigation and piloting of own ship by plotting own ship's track by radar fix and maintaining geographic plot, applying principles of advance, transfer, acceleration, deceleration, and set and drift	1
21. Perform CIC duties as part of A/S operations by maintaining geographic and surface plots during search, detection, attack, and retirement phases and by maintaining a strategic chart on A/S situation	1

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Qualifications for Advancement in Rating	Applicable Rate
	RD
101 OPERATIONAL—Continued	
22. Perform CIC duties related to tactical communications by organizing assigned communications equipment, facilities, and personnel to implement communications plans	1
23. Take measures to restore CIC operations under battle and emergency conditions, including fire, personnel injuries, and loss of or damage to radars, MC units, S/P telephones, lighting, DRT, gyros, power, plots, and status boards	1
24. Perform CIC duties related to AA coordination including target indication, designation, and acquisition	1
25. Perform the functions of air control in situations requiring the control of aircraft which do not involve GCA, CCA, and air-to-air intercept	1
26. Instruct personnel in principles of radar and electronic countermeasures operations	1
27. Set up a radio receiver patch panel in CIC and patch into operating position	1
28. Tune a radar manual frequency control	1
29. Perform functions of air control in all situations involving control of aircraft, excluding GCA and CCA	C
102 MAINTENANCE AND/OR REPAIR	
1. Observe safety precautions in connection with operating and maintaining electronic equipment	3
2. Demonstrate under simulated conditions the rescue of a person in contact with an energized electrical circuit, resuscitation of a person unconscious from electrical shock, and treatment for electrical and acid burns	3
3. Locate and identify units and component parts of radar and electronic countermeasures equipment to which assigned	3
4. Inspect indicator lamps and fuses and replace as necessary	3
5. Demonstrate, while servicing equipment, safety precautions such as tagging switches, removing fuses, grounding test equipment, using shorting bars and rubber mats	3
6. Repair radio headsets and microphones	3
7. Define common electrical and electronic terms used with radar equipment such as: Volt, ohm, ampere, watt, henry, farad, cycle, reactance, impedance, capacitance, inductance, frequency, and modulation	3
8. Identify, by reference to block diagrams, circuits affected by operation of associated external controls	2
9. Identify circuit components such as electron tubes, resistors, and capacitors	2
10. Inspect, clean, lubricate, and make adjustments on radar and electronic countermeasures equipment to which assigned, as specified in routine POMSEE checkoff lists	2
11. Test electron tubes for operational effectiveness and replace those found defective or below standard	2
12. Use test equipment, such as tube testers, multimeters, and output meters, required in operational and preventive maintenance of radar equipment and associated electronic countermeasures equipment	2

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Qualifications for Advancement in Rating	Applicable Rate
	RD
102 MAINTENANCE AND/OR REPAIR—Continued	
13. Perform routine tests on electronic equipment	2
14. Read color codes and circuit markings to identify electrical characteristics of circuit components and connections	2
15. Identify, in schematic diagrams, basic circuits such as amplifiers, oscillators, mixers, and rectifiers	2
16. Interpret electronic wiring and circuit diagrams found in technical manuals	2
17. Locate and identify maintenance test points of equipment to which assigned, as specified in technical manuals	2
18. Supervise and train personnel in operational and preventive maintenance procedures, as specified in technical manuals for electronic equipment to which assigned	1
19. Locate electrical and electronic circuit failures, employing systematized procedures for isolating inoperative sections of radar and electronic countermeasures equipment as specified in technical manuals	C
103 ADMINISTRATIVE AND/OR CLERICAL	
1. Prepare and maintain CIC operations logs, radio circuit logs, contact logs, and operating logs for equipment to which assigned	3
2. Prepare stub requisitions for CIC supplies	3
3. Enter corrections to:	
a. Publications issued to CIC	3
b. Nautical charts issued to CIC	3
4. Locate in tactical publications and OP orders information relative to CIC functions	3
5. Maintain records of intercepted electromagnetic radiations in accordance with current electronic countermeasures doctrine	2
6. Assign responsibilities to and supervise individual CIC personnel performing manipulative functions involved in operating surveillance and height-finding radar and associated equipment	2
7. Prepare required BuShips electronic failure reports	2
8. Prepare requests for survey and requisition of equipment, parts, and supplies	1
9. Prepare naval shipyard and tender work requests	1
10. Supervise individual performance of personnel operating electronic countermeasures equipment	1
11. Supervise and train personnel in operating interrelationships as a CIC team	1
12. Serve as assistant to CIC watch officer during condition watches	1
13. Serve as assistant to CIC officer in general administration of CIC enlisted personnel	C
200 EXAMINATION SUBJECTS	
201 OPERATIONAL	
1. Nomenclature of the following equipment: Surveillance and height-finding radar, IFF, and associated equipment	3

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Qualifications for Advancement in Rating	Applicable Rate
	RD
201 OPERATIONAL—Continued	
2. Principles of operation of surveillance and height-finding radar, IFF, and associated equipment	3
3. Procedures for operating remote plan position indicators (RPPI)	3
4. Procedures for adjusting parallel motion protractor equipment and position bug, and for making appropriate scale and quadrant setting on dead-reckoning tracer (DRT)	3
5. Procedures for starting, stopping, and operating remote control units used for radio telephone	3
6. Evaluation of radarscope presentations caused by different types of contacts	3
7. Symbols and procedures used in maintaining geographic, summary, and surface plots	3
8. Procedures for solving the following types of maneuvering board problems: Determination of course and speed of contact, closest point of approach of contact, and maneuvering to a new position	3
9. Information to be gained from nautical charts, including symbols, topography, depth, and variation	3
10. Procedures for plotting on nautical charts, including ranges, bearings, radar fixes, determination of courses, distances, and set and drift	3
11. Definitions of terms used in surface formation, screening, and general maneuvering	3
12. Procedures for converting given positions into grid coordinates; conversion of polar to grid coordinates and grid to polar coordinates	3
13. Standard vocabularies, procedures, and techniques used in transmitting and receiving on CIC radiotelephone circuits, as defined in communication doctrinal publications	3
14. Interior communication procedure and communication facilities associated with CIC operations	3
15. Radar search procedures	3
16. Electronic characteristics and operational features of the following equipment by type: Surveillance and height-finding radar, IFF, and associated equipment	3
17. Nomenclature of sections and principles of operation of electronic countermeasures equipment	2
18. Classification of intercepted electromagnetic radiations	2
19. Capabilities and limitations of electronic countermeasures equipment	2
20. CIC procedures in control of electronic countermeasures	2
21. Capabilities and limitations of CIC communication equipment and facilities	2
22. Information supplied by CIC in normal cruising conditions and special exercises	2
23. Principles of operation of shipboard AEW terminal equipment and associated indicators	2
24. Relationship of airborne early warning (AEW) to shipboard CIC operations	2
25. Procedures for solving advanced maneuvering board problems	2
26. CIC procedures in assisting in navigation and piloting, including contour and VPR methods of radar navigation and radar navigation in station taking	1

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Qualifications for Advancement in Rating	Applicable Rate
	RD
201 OPERATIONAL—Continued	
27. CIC procedures in assisting in A/S operations, including internal and external communication requirements	1
28. CIC functions and procedures in tactical deception	1
29. CIC functions and procedures in AA coordination, including target indication, designation, and acquisition	1
30. CIC functions and procedures in assisting in naval gunfire support	1
31. CIC functions and procedures in assisting in torpedo control	1
32. Functions of air control in situations requiring control of aircraft which do not involve GCA, CCA, and air-to-air intercept	1
33. CIC procedures in control of small craft, including small craft involved in amphibious operations	C
34. Functions of air control in all situations involving the control of aircraft, excluding GCA and CCA	C
202 Maintenance and/or Repair	
1. Safety precautions to be observed in connection with operating and maintaining electronic equipment	3
2. First-aid procedures for treatment of electrical shock and burns	3
3. Standard symbols used in schematic diagrams	3
4. Reading and interpretation of block diagrams	3
5. Inspection, cleaning, and lubricating procedures for motors and generators	3
6. Elementary electricity; simple problems in a. c. and d. c.	2
7. Definitions of common electrical and electronic terms used with surveillance and height-finding radar equipment	2
8. Handling and testing electron tubes	2
9. Purposes and uses of test equipment in performing operational and preventive maintenance	2
10. RETMA color codes and circuit markings used to identify and describe electrical characteristics of circuit components and connections	2
11. General content of technical manuals	2
12. Functions and interrelationships of the following radar components: Modulator, transmitter, receiver, antenna, control unit, and indicator units	2
13. General effect of circuit components such as resistors, capacitors, and inductors on flow of direct and alternating current	2
14. Procedures and purposes of routine tests on electronic equipment	2
15. Functions, physical structure, and operating principles of electron tubes used in electronic equipment	2
16. Functions of basic circuits such as rectifiers, amplifiers, oscillators, detectors, and band-pass filters	2
17. Uses and procedures for preparing BuShips electronic failure reports	2
18. Method of determining values of resistors and capacitors	2
19. Basic theory of resistance, capacitance, and inductance	2

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Qualifications for Advancement in Rating	Applicable Rate
	RD
201 OPERATIONAL—Continued	
20. Reading and interpreting circuit schematic diagrams	1
21. Calculate current, resistance, and voltage through any part of a circuit	1
22. Characteristics of a. c. and d. c. current	1
23. Operating principles of basic circuits such as rectifiers, amplifiers, oscillators, detectors and band-pass filters . .	1

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INDEX

Advancement in rating 1
  correspondence courses 4
  qualifications for 332
  quals manual 3
  requirements for 2
  study techniques 4
Air plotting 242-259
  AA coordination 255
  conversion plotting 254
  dead reckoning 251
    developing track 251
    orbit and turns 253
    speed converting 252
    turns 252
  ECM information 256
  GEOREF system 243
  status board 255
    abbreviations used 256
  strategic plot 258
  summary plot 242
  symbols and abbreviations 244
  techniques of 246-249
  tote board 249-251
Airborne radars 87
Air-search operations 124-126
Air-search radars 84-85
  altitude determination 46
Altitude determination 45
  Air-search radar 46
  radars 86
Answer to quizzes 323-331
Antennas 53-65
  AN/SPS-10 61
  directional type 56
  horizontal radiation pattern 57
  induction field 54
  polarization effect 65
  radiation field 55
  radiation patterns 56-58
  reception 56
  transmission lines 63
  types of 59-61

Bearing
  cursor 45
  determination 44
  factors affecting accuracy 142
  factors affecting resolution 144
  plotting of 290
  radar fix, use 316
  tangent-bearing fix 318
  3-bearing fix 317
  3-range fix 319

Cathode ray tube (CRT) 23
  brightness, focus control 24
  electromagnetic CRT 26
  electrostatic CRT 25
Charts 302-309
  consecutive numbers 306
  H. O. numbers 303
  stowing of 302
CIC communication methods 183
  circuit discipline 201
  circuit requirements 195
  circuits, sound powered 194
  console equipment 187
  MC system 184-187
  phone procedure 196
    code words 198
    numeral pronouncing 199
    phonetic alphabet 200
    words and phrases 197
  report terminology 201
    contact designation 202
    standard terms 202, 203
  sound powered circuits 194
  sound powered phones 188-193
CIC doctrine 120
CIC navigation functions 309-311
CIC publications 215
  tactical 216
Circuit faults 167
Circuits, radar 67
Circuits, special 123
Combat Information Center (CIC)
  control and assist functions 30
  data collection 28
  development of 28
  functions of 28
  information evaluation 30
  organization of 30
  personnel responsibilities 31
  types of display 29
Communication status board 240
Course and speed problems 270

Dead reckoning (air plotter) 251
Dead reckoning system 280
  analyzer (DRA) 280
    pitometer log 282
    pitometer log indicator 283
  developing ship's track 289
  DRT casualties 294
  geographic plotting 287
  parallel motion protractor (PMP) 288
  plotting bearings 290

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Dead reckoning system -- (Continued)
plotting method 290
3-minute rule 293
plotting symbols 296
recording data 293
sample DRT plot 295
target course and speed 292
tracer system (DRT) 281
adjusting for charts 314
alignment procedure 289
"bug" controls 286
drive system 284
operating controls 284
scale adjustment mechanism 286
tracer mechanism 285
Detecting and tracking 118
Dipole antenna 54
radiation pattern 57

Echo Box
measuring ring time 92, 93
power checking 93
sensitivity checking 94
testing equipment with 91
Electric current, measuring of 9, 170-176
devices used 170
electric meter 171
reading of 175
multirange ammeter 172
ohmmeter 174
units of resistance 174
voltage 173
Electrical, electronic terms 8-14
ampere 10
capacitance 12
capacitive reactance 12
condensers 11
conductors and insulators 9
cycle 12
frequency 13
impedance 12
inductance 11
inductive reactance 11
modulation 12
ohm 11
volt 10
watt 11
wavelengths 13
Electron theory 8
Electron tubes 19
cathode ray tube (CRT) 23-26
electron use in 20
physical structure 21
types of 22
Electronic equipment
cleaning and inspecting 166-170
air filters 169
cabinets 168
electrical components 169
tubes and sockets 170
operating techniques 88
power losses, effect on 89
radar performance checks 96
starting precautions 88, 89
Equipment indicator letters 7

Faults, circuit 167
Fix
range 319
3-bearing 317
Functions, CIC 28

GEOREF system 243

Height finder operator 120

Indicators (PPI) 98-117

Logs, CIC 205-212
alterations to 212
radar performance 210
radio telephone 209
Watch Log 206-209

Maintenance, preventative 164-170
trouble shooting procedure 177
POMSEE program 174-182

Maneuvering board 260-279
course and speed problems 270
point of closest approach (CPA) 266-278
determining of 267
problems 270-278
time of 269
problems solving 265
techniques used 278
relative movement plot 261, 262
relative plot 263
vector diagram 264
tactical use of 260

MC system 184-187
Mercator projection 301
Message procedure 196-200
Model letter identification system 7, 8

Nautical mile 301
Navigation 298
charts 300
correcting of 306-308
DRT use 314
measuring distances on 313
mercator projection 301
numbering system 303
ordering 308
scale used 314
determining, heading, speed 320-321
obtaining radar fixes 316
tangent bearing fix 318
3-range fix 319
two or more ranges 317
piloting 298
piloting team organization 309
CIC JA talker 310
personnel functions 311

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Navigation — (Continued)
plot 299
locating position 300
plotting ship's track 312
moving and fixed object track 313
portfolio chart list (1-PCL) 303
maintaining card system 306
use of 305
scope interpretation 318
set and drift 318
determination of 320
soundings 314
aid to navigation 314

Operational techniques 118-135
basic operating problems 124
CIC doctrine 120
detecting and tracking 118
E-units system 128
height-finder operator 120
duties of 125
IFF system 128
performance log 127
radar control officer (RCO) 119
radar guard assignments 120
radar tracking 129
search adjustments 121
antenna scan 122
receiver gain 122
scope controls 122
special circuits 123
search operator 118
search procedures 124
air search 124
low plane 125
small objects 127
surface searching 126
special tracking 130-134
aircraft control 133
CIC assistance 130
small craft control 134
station keeping 131
target evaluation 127

Performance tests, radar 96
Phonetic alphabet 200
Piloting
CIC functions 309-311
PIP's 150-163
airplanes, numbers 153
characteristics 150
false contacts 156-160
lobe echoes 157
miscellaneous types 160
multiple range echoes 158
sea return 156
thunderstorms 159
land targets 154
one PIP areas 152
plane targets 156
ship targets 155
target identification 151

Plan position indicators (PPI) 98-117
accessory devices, functions 101
AN/SPA-4A operation of 100
video gain and intensity 101
basic type 99
off-center PPI 106
floating cursor type 106
PPI repeaters 102
delayed PPI 102
large diameter 102
projection type 102
range-height (RHI) 114
VL-1 operation 115-117
VL-1 remote indicator 114
remote PPI 98
AN/SPA-8, 8A, 9 110
AN/SPA-8A (illus) 11
AN/SPA operations 112-114
VJ remote indicator 103-105
illustration of 104
operating techniques 105
operator's controls 104
VK radar repeaters 107
VK2, VK4 functions 107-109
VK4 model (illus) 108
Plotting
air 242-259
bearing 290
surface 225-241
Plotting symbols, DRT 296
Point of closest approach (CPA) 267, 269
problems 270-278

POMSEE program 179
Maintenance Standards Books 179
Performance Standards Sheets 179

Portfolio Chart List (1-PCL) 303, 306

PPI interpretation 161-163
distortions 162
pattern analysis 162
radar shadows 161
Presentations
A-scan 37
B-scope 40
continuous, discontinuous sweeps 38
PPI-scope 39
R-scope 39
RHI-scope 42
special purpose 42
Preventive maintenance 164
air filters 169
electrical circuits 167
electrical components 169
forms used 180, 181
POMSEE program 179
records of 180
resistors 176
routine maintenance 178
trouble shooting procedure 177
tube testing 176
tubes and sockets 170
Use of handbooks 178

Digitized by Google

Publications, CIC 215-216
hydrographic 303
Index Catalogs 304
Notice to Mariners 305

Pulse Repetition Rate (PRR) 49
Pulse width (PW) 49

Qualifications for Advancement in Rating 332

Radar control officer 119
Radar equipment
basic types 32-36
component indicator letter 7
fade areas, causes 47
indicator letters 6
model letters system 7
nomenclature designations 6-8
performance checks 96
Radar repeaters 99-114
Radar set, AN/SPS-10
basic principles 80
block diagram 78
functions of units 73-76
functional operation of 77-84
operational checks 81
pre-checks 80
selector switch positions 83
starting of equipment 81
tuning adjustments 83
unit relationships 74
Radar system components 48-68
antenna systems 53-56
antenna types 59-62
description of 48
duplexer 63
functional parts (illus) 50
horn radiators 62
indicators 66
keyer or modulator 52
circuits 53
magnetron diagram 51
overall operation of 67
peak power supply 49
scan, types of 62
superheterodyne receiver 65
system constants 48
timer 50
transmission lines 63, 64
transmitter 50
waveguides 64
Radar system operation 15-31
block diagram of 16
CIC and radar 28-31
display, types of 29
electron tubes, used 19-26
heighth and direction, finding 17
historical development 27
operating principles 15
radio wave reflection 17
sound wave reflection 15
radar methods
continuous wave 26
frequency modulation 27
pulse modulation 27
Radar tuning 90-97

Radar, uses 32-47
air-search 33
altitude determination 45
bearing determination 44
factors affecting, 136-149
altitude determination 145
bearing accuracy 142
bearing resolution 144
external 146-149
range 136
range accuracy 137
range resolution 139
fire control 34
guard assignments 121
information obtained 36
range determination 42
search radar 32
special types 35
heighth-finding 35
IFF 35
GCA 36
range rate 36
surface search 33, 69-72
types of presentation 37-42

Radio wave
polarization 65
Range determination 42
range ring 43
range markers 43
Records and reports 205-224
checkoff tests 213
CIC logs 206-210
information sources 205
Electronic Failure Report (DD787) 223
operational reports 223
compiling of 221
training records 212
work requests 219
Relative movement plot 261

Safety precautions 165
high voltage 165
shorting bar, use 166
Search operator, duties 118
Soundings 314
Status boards (air) 256
Submarine radars 87
Summary plotting board 232
Supplies (CIC) 216-220
GSM material 217
Navy Stock List 217
requisitions 216
Surface plotting 225-241
bearing, plotting 229
checkoff list 236
definitions and terminology 228

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Surface plotting -- (Continued)
formation diagram 237-239
geographic plots 230
plotting procedure 234
scale requirements 231
status boards, used 239-241
summary plot 236
summary plotting board 232
symbols used 233
target angle 229
to prevent collision 235
types of 230
typical situation 225
information flow 226
information passing 228
information to bridge 228
personnel duties 226-227
Surface search, procedure 126
Surface search radars 70
equipment layout 69
model descriptions 72
search procedures 126
unit relationship (illus) 71
Surface status board 239
Surveillance radars 69-97
Symbols
surface plotting 233
DRT 296
air plotting 245, 249
surface 233

Tote board (air) 249-251
Trouble shooting procedure 177
Telephone, sound powered
advantages of 195
circuit 194
nomenclature 195
requirements 195
headset operation 190-192
care of 193
securing of 192
plug-in jacks 189
theory of 189
use of 196-204
Telephone, talking procedures 196-204
brevity codes 198
numeral pronounciation 199
phonetic alphabet 200
report terminology 201-203
words and phrases 197

Tracking operator 119

Tracking procedures 129-134
aircraft control 133
auxiliary fire control
CIC assistance in 130
gunnery liaison 134
interference 133
small craft 134
station keeping 131
Tuning, radar 90-97
controls 94
duplexer 96
echo box, use 90
receiver 95

Vector diagram 264

Watch log 206-209
sample entries 207
Work requests 219
shipboard 219
ship's memorandum 221
tender, and repair ship 219
Waveguides 64

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